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Restoration of the Biological Communities
of the
Grand Calumet River Basin

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Cover: A series of photographs of the Grand Calumet River in northwest Indiana. Larger photographs are printed in the text of this volume. The river, in a highly industrialized area, parallels the shore of Lake Michigan.

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PREFACE

RESTORING BIOLOGICAL COMMUNITIES OF THE GRAND CALUMET RIVER WATERSHED

Richard L. Whitman, U.S. Geological Survey; **Meredith Becker Nevers**, U.S. Geological Survey; **Philip B. Moy**, U.S. Army Corps of Engineers; **David A. Beamer**, U.S. Geological Survey; **Kenneth J. Brock**, Indiana University Northwest; **Young D. Choi**, Purdue University Calumet; **Spencer A. Cortwright**, Indiana University Northwest; **Timothy Fisher**, Indiana University Northwest; **Paul J. Gerovac**, U.S. Geological Survey; **Shira Hammann**, U.S. Geological Survey; **Laurel L. Last**, U.S. Geological Survey; **Kenneth S. Mierzwa**, TAMS Consultants; **Thomas P. Simon**, U.S. Environmental Protection Agency; **John O. Whitaker, Jr.**, Indiana State University

When the Chicago District of the U.S. Army Corps of Engineers approached me about writing a section of the dredging plan for the Grand Calumet River, I was pleased to hear that some efforts were being made to clean up this system. The Grand Calumet River has often been cited as one of the most polluted waterways of its type in the Midwest. To remove safely the years of accumulated toxic materials alone would be a formidable task, but the State of Indiana and local communities had additional plans. They hoped we could contribute ideas for restoring the ecology of the river habitat as much as possible. With this task in mind, I began developing restoration options for the river basin to be included with the dredging project. As I considered the ecology of the basin, however, I recognized that the river system operates within its watershed, and the riverine ecosystem depends on the riparian areas and habitats that surround it. Being an aquatic scientist, I had little acquaintance with the terrestrial habitats associated with the river. Luckily I knew a charismatic naturalist, Paul Labus, who had thought a lot about restoring the watershed. Paul's enthusiasm about improving and renewing the Calumet area was inspiring. Paul easily convinced me that we had to attend to both the prides and problems of the entire watershed: natural wetlands, forests, and grasslands; degraded sediments; undesirable exotics; lost habitats; and lost processes such as fire and flooding. As attractive as this whole-system approach was, we did not have the breadth of knowledge to write such a generalized, integrated plan. We knew enough specialists that had the collective knowledge to apply this approach; and thus we formed the team of individuals that wrote the plan essentially presented in this special issue. Each individual was chosen because of his or her broad understanding of the subject matter, experience with the Calumet Region, and commitment to restoring the watershed. I am deeply grateful for the contributions of their valuable time and considerable expertise.

This special issue in many ways may be considered a monograph of the plants, animals, and habitats of the Grand Calumet River watershed. Because many of the same elements exist throughout northwest Indiana, it generally describes the ecology of the Calumet Region. We begin the issue with a paper describing the geological and historical setting of the region. The biological papers are phylogenetically arranged: plants, macroinvertebrates, fish, herpetofauna, birds, and mammals. The final paper summarizes the recommendations of the individual authors and also reports the collaborated recommendations that resulted from a one-day conference of the authors. At this meeting we distilled the final recommendations, finding consensus or compromise in conflicting approaches.

I hope that we have accomplished a number of objectives with this special issue. First, I hope that we have provided an extensive ecological inventory and description of the Grand Calumet watershed and to some extent, the Calumet Region. I also hope that we have imparted a better sense of the valuable, interconnected, and vulnerable nature of the area. The watershed's environmental richness and complexity is contrasted with the industrialization and urban development that have critically isolated it and decreased its ecological resiliency and stability. Finally, I hope that this document demonstrates the potential for habitat and community restoration and the importance of this formidable but worthy task.

Northwest Indiana has areas with some of the highest biological diversity in the nation that have somehow remained despite the loss of habitat and natural processes, the introduction of invasive species, and environmental degradation. Information, good planning, timeliness, and commitment are essential for the ultimate goal of saving this natural treasure. We hope that this contribution, in some way, furthers that goal.

Richard Whitman
3 June 2002

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HISTORY AND ENVIRONMENTAL SETTING OF THE GRAND CALUMET RIVER

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ABSTRACT. The Grand Calumet River lies in an area of great ecological diversity, a result of the convergence of three biomes during glaciation. Over thousands of years the region and the river have changed ecologically due to ice retreat, lake level declines, settlement and industrialization. Settlement and industrialization have greatly accelerated the rate of change, and the Grand Calumet River and its basin are now subject to the added effects of years of direct pollution. For years, industries directly discharged into the waterway; and those contaminants remain locked in the sediment a century later. In order to preserve the remaining surrounding natural areas and to improve the Grand Calumet River, buried contaminants would have to be dredged from the river. Restoration needs to be implemented as part of the clean-up process, and recontamination should be prevented.

Keywords: Grand Calumet River, Calumet region, settlement, industrialization

Only 13 miles (21 km) long and with almost no natural surface drainage, the Grand Calumet River flows through one of the more industrialized areas in the United States. Once, the downstream section of the Calumet River system dominated most of northwestern Indiana (Fig. 1). Today, the highly modified Grand Calumet River forms one of the smallest watersheds in the region (Fig. 2). Despite intensive urban and industrial development, the Grand Calumet River Basin still contains extraordinary vestiges of once highly rich and varied natural communities. These communities, along with other remnant natural areas preserved and protected by both public and private groups, may still possess the potential for at least partial recovery. Any plan for recovery of the Calumet Basin from past damage will require a geologic/ecologic framework within which mitigation targets can be developed.

Changes over the course of Lake Michigan's geological history strongly influenced the landscape of the present Calumet region. Wind, erosion, and fluvial and lake recession helped produce dune and swale ecosystems; and climate and hydrology encouraged the formation of wetlands, forests, savannas and prairies. The convergence of three major biomes (eastern deciduous forest, boreal forest and tall grasslands), succession over a small area and a large variety of hydrological regimes (e.g., streams, lakes, wetlands) all helped make the Grand Calumet River Basin biologically diverse. Although it would seem that biodiversity should be low due to the elimination of local communities by scouring action of the Laurentian ice sheet (12,000 years ago), the present-day diverse communities are the result of recolonization from outside sources.

The habitat destruction seen today is not due to glacial ice but to industrial and urban development and the introduction of non-native, invasive species. The natural and wetland ecosystems have been cleared, drained, fragmented and cut by roads and railways during commercial and municipal development. Human enterprise dominates the landscape and controls the region. The Grand Calumet River has been a dumping site for industrial and municipal wastes. Little natural flow exists anymore due to channeling, deepening and flow augmentation.

Establishing a bond between the industrial, urban and natural areas is necessary to preserve the habitat that remains without destroying the livelihood that supports the Calumet basin region. Only by revitalizing some of the more heavily-damaged areas can the ecological integrity of the basin be restored to approximate its historical natural appearance and

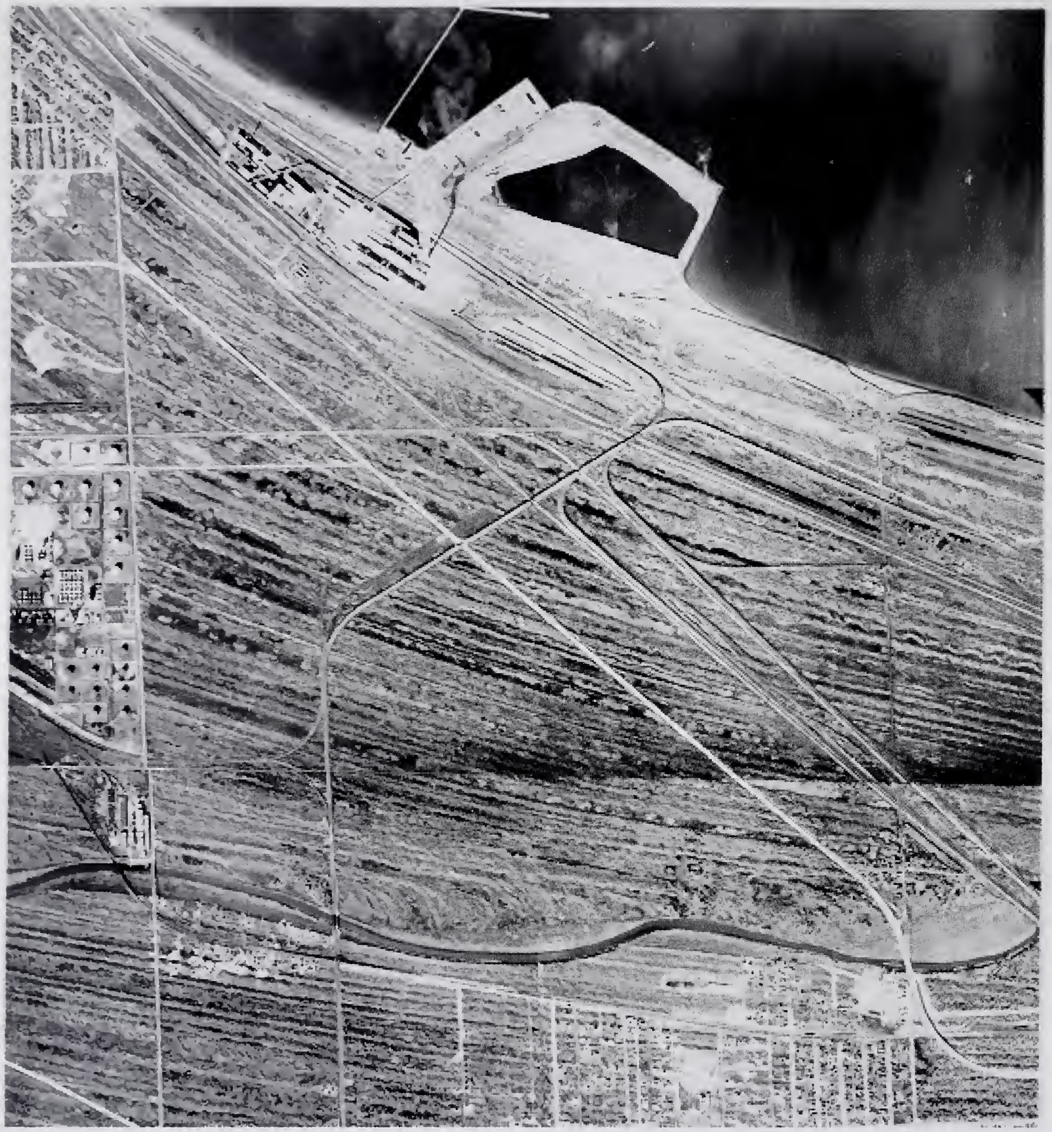

Figure 1.—Aerial photograph, taken in 1938, of a portion of the Grand Calumet River Basin study area, with Lake Michigan to the north. Compare with Figure 2 (facing page).

function. The remaining natural areas that were created over thousands of years by geologic and biologic forces must be preserved from further degradation, or the system's natural integrity might be irretrievably lost. The resiliency of nature is clearly illustrated by the biological recolonization and ecological recovery since the retreat of the last ice sheet. While this much time is not available for ecological restoration, natural restoration demonstrates the feasibility of a parallel human experiment.

Several questions need to be answered before carrying out this experiment in restoration. What is the status of the existing natural areas in the Grand Calumet River Basin? Can the remaining natural areas and present-day cultural pressures co-exist? Can sustainable natural communities be re-established? What is the most effective approach for re-establishing these natural communities? Finally, can enough social, economic, and political support be marshaled to attain these objectives? In an attempt to answer some of these

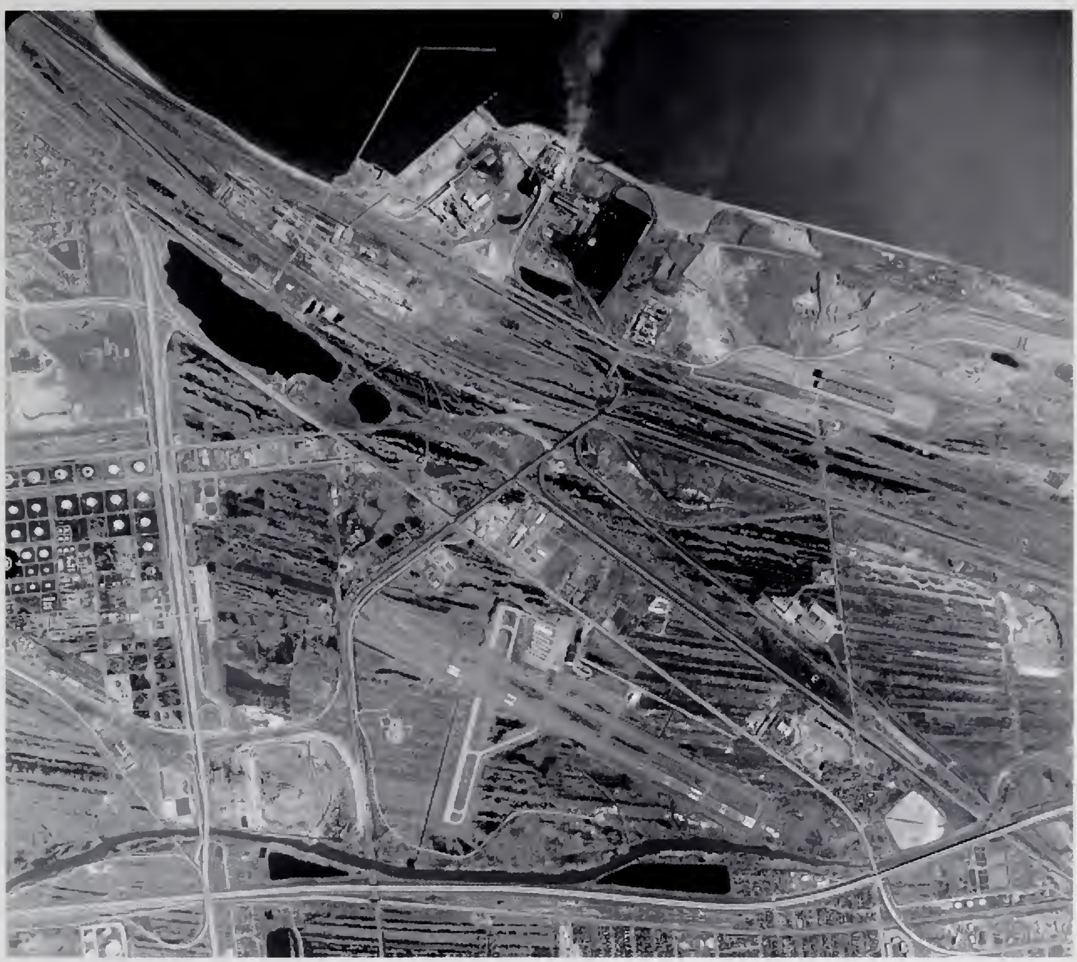

Figure 2.—Aerial photograph, taken in 1975, of a portion of the Grand Calumet River Basin study area, with Lake Michigan to the north. Compare with Figure 1 (facing page).

questions, the U.S. Army Corps of Engineers developed a remedial action plan with research and consultation conducted by scientists intimately familiar with the ecosystem and its components. The following papers are the culmination of these efforts and an attempt to answer the first four questions; the last question can only be answered after implementation of a restoration plan.

REGIONAL GEOGRAPHY

The natural watershed of the Grand Calumet River is located between Toleston Beach and the present-day shore of Lake Michigan (Fig. 3). The watershed lies within the Calumet lacustrine plain, or lake plain, which extends from the shore of modern-day Lake Michigan to the Valparaiso terminal moraine. After the Wisconsin glaciation, the Lake Michigan lobe of the Laurentian ice sheet began to retreat, and the Valparaiso terminal moraine marks the point of the ice sheet's furthest southward advance before receding. The moraine also serves as the continental divide and the southern boundary of the Lake Michigan watershed. Drainage from areas to the north of the moraine enters the Atlantic Ocean via the Calumet River, Lake Michigan, Lake Huron, the St. Clair River, Lake Erie, Lake Ontario and the St. Lawrence River. Drainage from areas south of the moraine typically flows to the Gulf of Mexico via the Mississippi River. The Calumet Basin lies on the

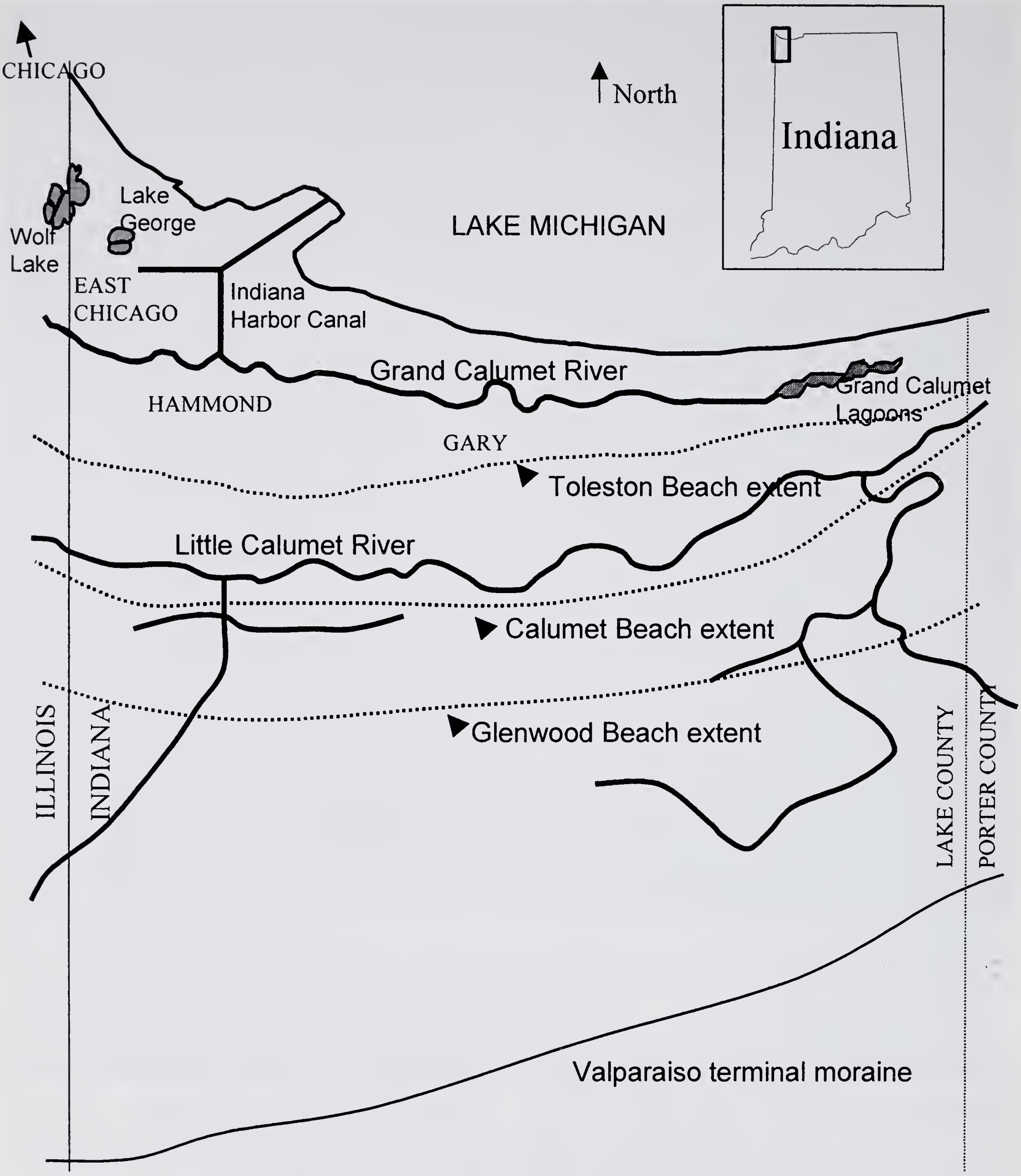

Figure 3.—Diagram of Grand Calumet River study region, with geological features highlighted.

northern side of the Valparaiso Moraine and is drained by the Calumet River system.

The last glacial retreat from the Great Lakes occurred about 18,000 years ago (Chrzastowski & Thompson 1992). As the glacier retreated, isostatic rebound caused lake levels to decline on three separate occasions. The archaic beaches—the Glenwood, Calumet and Toleston Beaches—remain today at 20, 12 and 6 m above contemporary Lake Michigan levels (mean = 176 m above sea level). Many ridges were built by wave activity and wind-blown dune deposits; and the valleys between them collected water, allowing the formation of marshes, ponds and swamps.

Changes in the drainage pattern of the lakeplain led to the formation of the Grand Calumet River. The Little Calumet River was located south of Toleston Beach, and drained into Lake Michigan near the current-day mouth of the Grand Calumet River. As lake levels fell, the Little Calumet began to create a basin moving east toward lower land levels where it could continue to drain into the lake (Chrzastowski & Thompson 1992). This stretch of river eventually reached an outlet near the present-day Grand Calumet Lagoons, and with changes in drainage patterns and the increased size of the new river basin, it was designated as the Grand Calumet River. Presently, the Little Calumet River continues to maintain a confluence with the Grand Calumet River to the west, in Illinois.

After retreat of the ice sheet, many habitats were created in the new, warmer environment. The cold climate biota (Arctic disjuncts, such as spruce and fir) followed the glacier's retreat northward as ambient temperature increased at a rate of 1–2° C every 1000 years (Schneider 1989). A few cold climate plants (e.g., bearberry, *Arctostaphylos uva-ursi*) adapted to the warming conditions. Extensive coastal marshes and wetlands formed between the dune ridges at the southern end of Lake Michigan, providing a rich habitat for shore birds, waterfowl, fishes, mammals, amphibians, reptiles, invertebrates and plants.

According to Bailey (1972), northwestern Indiana was dominated by open spruce forests 12,000 years ago. From 11,000–10,000 years ago, red and jack pines were dominant, and from 10,000–2,500 years ago, the area was covered primarily by oak-dominated hardwoods. Finally, mesic species such as beech, maple, oak and butternut took over. Surveys made during the period 1829–1834 list the most important trees in the dune complex communities as black oak (*Quercus velutina* Lam.), white pine (*Pinus strobus* L.), jack pine (*Pinus banksiana* Lamb.), white cedar (*Thuja occidentalis* L.) and tamarack (*Larix decidua* Mill.) (Bacone & Campbell 1983).

EARLY CULTURE

Early artifacts found on the back dunes of the Calumet Beach Ridge included fire-cracked rock, chipped stone tools, lithic debris and ceramics of the Late Woodland Stage (Lynott 1998). The earliest historic records are of the Potawatomi who occupied the area until about 1833. The Potawatomi were nomadic. During the summer they lived in the Calumet region, where they hunted, fished, foraged and cultivated; then, they moved south for the winter. Food was abundant for the Potawatomi. Wild currants, cranberries, whortleberries, gooseberries, huckleberries and wintergreen berries were plentiful between the dunes and swales. Other abundant foods were grapes, pawpaws, wild plums, crabapples, hazel nuts and sassafras. Honey and maple syrup were collected. Wild game included whitetail deer, black bear, wild turkey, prairie chickens, geese and ducks. Early European settlers traded tobacco and food with the Potawatomi for fur, cranberries, venison and beadwork.

The United States government bought much of the Potawatomi land between 1826–1832, and then extensive European settlement began. In 1832, most of the Potawatomi were removed to a reservation in Kansas, though some remained in the area (Meyer 1956). The settlers eagerly cleared the dense forest and cultivated the land wherever possible; much of the area was too wet to cultivate. The Grand Calumet and Little Calumet Rivers meandered lazily through impassable marshes, making travel in the area difficult as well. Transporting goods to outside markets was costly; and, consequently, the settlers were subsistence farmers of wheat, oats, corn, turnips, buckwheat and potatoes (Meyer 1956).

Traffic across the Calumet Basin became heavy as settlement increased to the west. Any travel from Chicago to the east had to cross the basin because of the presence of Lake Michigan (Cook & Jackson 1978). A mail route was established in 1831; and, in 1833, a stage began operating between Chicago and Niles, Michigan (Cook & Jackson 1978). As a crossroads, the Calumet region was ideally suited for industry and commerce; and eventually, they dominated the landscape.

INDUSTRIALIZATION

The sawmill quickly became the most important industry for the settlers. Mills were located in the heavily-wooded sections of the Calumet Basin; but due to the low flow of the Grand Calumet River, only the Little Calumet was used to transport lumber (Meyer 1956). Gristmills, another large industry, appeared along with cultivation. Though ideally situated near the prairies, the gristmills actually had to be located near the river; therefore, they sprang up near the sawmills in the forested areas. Other tradespeople, including blacksmiths, wagon makers, coopers, tanners and cabinetmakers, soon moved into the area. As logging continued and sand mining increased, the Grand Calumet River began to be impacted. Forests were removed; and, within 20 years, a 55 m sand dune was leveled (Lerner & Trusty 1977). Understandably, erosion became a problem.

In the 1840s, heavy industry began to enter the Calumet Basin as a result of the area's blooming transportation network. By 1848, the Illinois Central Railroad traversed the Calumet Basin; and, in 1852, the Michigan Southern and Northern Indiana (South Shore) Railroads connected the region to the east and west. The settlement rate increased along with employment opportunities on the railroad. The railroads also made transporting heavy farm equipment into the region possible (Cook & Jackson 1978).

Water transport was also important in settling the Calumet region. The Grand Calumet River was eventually channeled to create a navigable waterway. In 1862, the Calumet Feeder Canal was built to allow the Grand Calumet River to flow east into the Illinois and Michigan Canal (I&M). This project reversed the east flow of the river, causing the Grand Calumet River to flow toward the canal from the east and the west and to empty into Lake Michigan via the canal. This change eventually caused the closing-off of the eastern river mouth. The current Grand Calumet Lagoons are part of, and located near, the former river mouths. Other construction projects included removing sand bars, erecting piers and straightening and narrowing the channel. In 1870, the federal government began constructing the Calumet Harbor to make the river a navigable passage for ships (Moore 1959). By the early 1900s, the Indiana Harbor Ship Canal had been constructed by the East Chicago Company; and the Grand Calumet River was effectively connected to Lake George, Wolf Lake and Lake Michigan (Moore 1959). With several major modes of transport available, further industrial expansion was inevitable. The accumulation of sediment and contaminants became a problem in the Grand Calumet River around 1885. Effluent was directly discharged into the waterway by foundries, refineries, packing plants, inadequate sewage treatment plants and, eventually, steel mills (Moore 1959).

The first major industry in the area was a meat packing company, the George H. Hammond Packing Company, which slaughtered and shipped meats to the eastern United States and Europe with a patented refrigeration process (Moore 1959). The Calumet Basin began to change dramatically and rapidly with the arrival of Standard Oil in 1889 (Moore 1959). Inland Steel was built as a separate plant in 1902, and the city of Gary (the site was selected due to its proximity to Chicago) was established with the building of U.S. Steel in 1905. Another steel company, Midwest Steel, purchased land in the area in 1929; and expansion continued (Cook & Jackson 1978). Dredging the Grand Calumet River was futile because pollutants entered the basin faster than they could be removed. Severe air pollution was evident by the 1920s.

With the growth of industry came population expansion. Small family farms were disappearing due to the urbanization that accompanied industrialization (Meyer 1945). Immigrants from all over Europe and Mexico came to the area for work in industry (Lerner & Trusty 1977). The region was changing quickly.

With the onset of the Great Depression, industrial expansion experienced a lull that extended through World War II and into the 1950s (Cook & Jackson 1978). Nevertheless, the effects of industry already present were still apparent. In 1930, the Grand Calumet River was described by Peattie (1930) as a stagnant lagoon, an "open sewer" devoid of plant life, though bordering marshes still offered "favorable localities for plant growth." In 1966, the chief contributors to air pollution were fossil fuel combustion (41% or 458,000 tons/year), industry (35% or 392,000 tons/year), transportation (22% or 241,000 tons/year) and refuse disposal (0.02%) (Lerner & Trusty 1977).

Industrialization created the landscape we see today. The Grand Calumet River experienced the full force of pollution inherent in industry and urbanization. After years of unmanaged pollution arising from rapid industrial growth and urbanization, numerous pollutants are now buried in the sediments; and the ecological integrity of the watershed has been severely degraded.

POLLUTANTS

The 1972 Federal Water Pollution Control Act required the Indiana Stream Pollution Control Board to issue permits to stream dischargers through the National Pollution Discharge Elimination System, and an opportunity for reviving the Grand Calumet River was granted. The steel mills removed solid and acid wastes from their effluent by installing catch basins and using aeration and filtration techniques. Though numerous cases of noncompliance have been reported, the National Pollution Discharge Elimination System remains a recognized contributor to improved water quality in the basin.

Recognized pollutant sources include urban runoff, landfills, dumpsites, industrial effluent and sewage treatment plants. Historically, the Grand Calumet River has had high levels of bacteria, nutrients, cyanides, lead, arsenic, cadmium, PCBs, phenols, oils, grease, chlorides and other contaminants in both the water and sediments (Lerner & Trusty 1977). Combined sewer overflows from Gary, East Chicago and Hammond sewage treatment plants flush raw sewage and fecal contamination into the Grand Calumet River and also into Lake Michigan via the Indiana Harbor Canal.

The negative effects of these pollutants on humans and the river's ecology are great. Ammonia is released in the coking operation of steel production, and both ammonia (nitrogen) and phosphorus are found in sewage, fertilizer, meat packing and industrial waste and detergents. Nitrogen and phosphorus, when flushed into Lake Michigan, contribute to toxic algal blooms, increased aquatic plant and algal growth and lower oxygen levels. High nutrient levels clearly create problems for the lake's ecology and its fisheries.

Despite successful attempts to improve the river's water quality, the sediments will not be cleaned simply by changing current pollution practices. For over 100 years, contaminants have accumulated in the sediments; and only by removing them completely will the river's ecosystems be improved. The toxic effects on the environment surrounding the river are biologically acute, and many of the river's reaches are still as devoid of life as Peattie (1930) observed years ago.

CONCLUSIONS

The fast pace of industrialization has taken its toll on the environment of the Calumet Basin. Some natural areas still survive, and preserving and expanding these habitat fragments will help to restore the integrity of the Grand Calumet River and its surrounding environs. Dredging the sediment is a first step in the process; and by dredging, years of industrial degradation can be removed from the river. However, merely dredging the main channel is ecologically inadequate. Watersheds are intricate systems that must be restored and managed at an ecosystem level. Components of the Calumet watershed include riparian wetlands, slack water, savannas, prairies, and dune and swale habitats. Restoration should be integrated, proportional and with clearly targeted recovery objectives. Preventing recontamination will be an important part of restoration; and, with the appropriate regulations in place, the Grand Calumet River may eventually regain some of its natural beauty and function.

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GEOLOGY OF THE GRAND CALUMET RIVER REGION

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ABSTRACT. The geology of the Calumet River region is briefly reviewed to provide a background for applied research in the area. The review relies heavily upon research conducted by scientists affiliated with the Indiana and Illinois Geological Surveys. At the end of the Late Wisconsinan glacial epoch, fluctuations in the Lake Michigan Lobe of the Laurentide Ice Sheet resulted in the formation of three moraine systems around the south end of the Lake Michigan basin: in decreasing age, the Valparaiso, Tinley and Lake Border ridges. High stands of ancestral Lake Michigan (also known as glacial Lake Chicago) are named the Glenwood, Calumet and Algonquin high phases that formed when the north end of the basin was blocked by ice. Retreat of the glacier from the basin caused the lake level to drop during the Two Creek low phase. The Chippewa low occurred at the beginning of the Holocene when ancestral Lake Michigan was as much as 107 m below modern levels. Lake level then rose in response to isostatic rebound of the outlet in southern Ontario until the Nipissing high was reached about 5000 years ago. At this time, the Toleston Beach in northern Indiana and Illinois was developing as a complex of sand dunes and more than 100 beach ridges. The Grand Calumet River came into existence about 2600 years ago as spits deflected the Little Calumet River eastwards upon closure of the Sag channel. Eastward migration of the Grand Calumet River ceased when the coastline was modified following European settlement in the late 19th century.

Keywords: Indiana, Lake Michigan, Grand Calumet River, geology

The geology of the Grand Calumet River region (hereafter referred to as 'the region') is closely tied to glacial events that began about 1,600,000 years ago. During the Pleistocene epoch (≈1,600,000–10,000 years ago) the region was impacted by numerous glacial advances and retreats. Because successive glacial advances destroyed the evidence of previous advances, the number of glaciations is unknown. The presence of older glacial sediment throughout the Midwest beyond the limit of the late Wisconsinan glaciation (Fig. 1), which peaked about 20,000 years ago (Mickelson et al. 1983), is testament to earlier, more extensive glaciations. In the region there appears to be sedimentary evidence for only the most recent glacial episode (Brown et al. 1996), although there may be some uncertainty about this. The geology of the region is by no means only a result of glacial erosion and sedimentation. Much of the sediment in the region was deposited as littoral sand or offshore mud from various levels of glacial Lake Chicago and mid-Holocene age Lake Michigan. The variable levels of these lakes developed in response to the presence of ice in the Lake Michigan basin and isostatic rebound in Ontario.

Time (radiocarbon dates) within the text older than 6300 ybp (years before present [1950]) is in radiocarbon years, while dates younger than 6300 ybp are reported in calendar ybp.

GLACIAL AND GLACIAL LAKE HISTORY

The region is underlain by sediment deposited by glaciers and glacial lakes. The Grand Calumet River is located on lacustrine sediment of the Toleston Beach that is less than 6300 years old, which in turn lies upon older glacial, and finer-grained glaciolacustrine sediment. The distribution and character of this older sediment is best understood by linking the history of the recessional ice margin with glacial lakes in the Lake Michigan basin.

During the last ice age, known as the Wisconsinan in the Midwest, the Laurentide Ice Sheet advanced across much of Indiana, Illinois, and Ohio (Fig. 1); and the maximum extent of ice was reached about 20,000 ybp. Across Indiana, there are series of recessional moraines that record stationary ice-margins (Gray 1989) composed of glacigenic material (sand, gravel, and till). By about 14,000 ybp

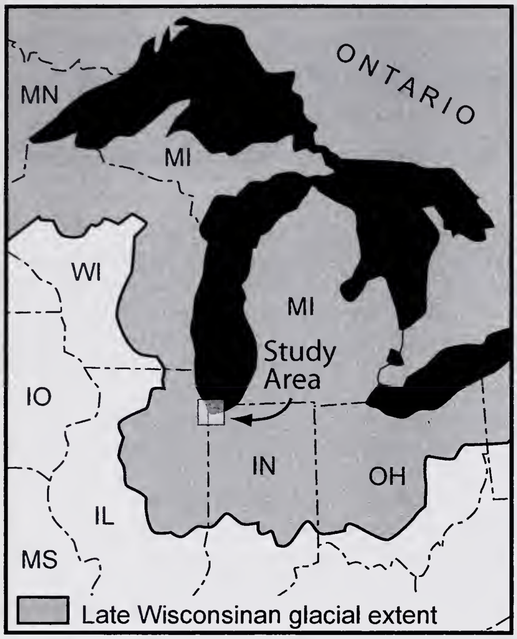
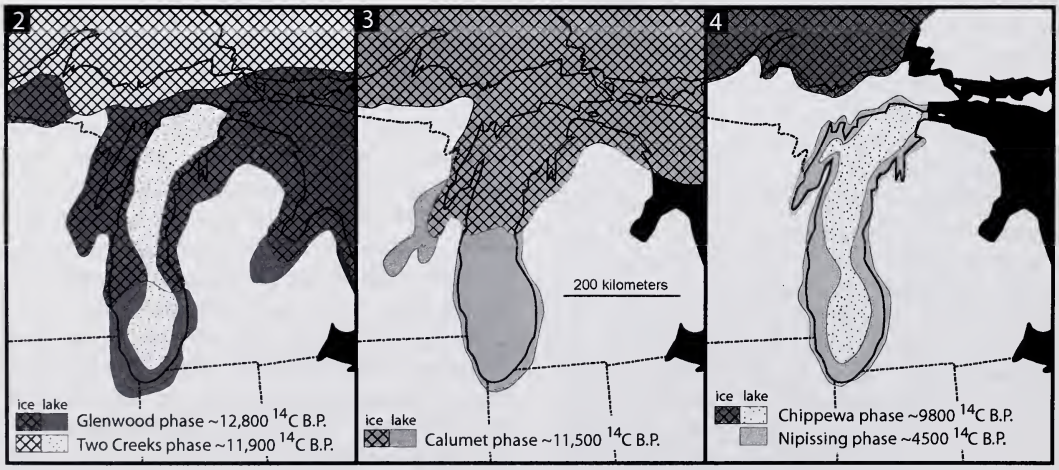


Figure 1.—Location of the Grand Calumet River region at the southern end of Lake Michigan, and the extent of Late Wisconsinan glaciation in the Great Lakes region.

(Hansel et al. 1985) much of the Laurentide Ice Sheet was confined to the Great Lake basins, giving a lobate pattern to the ice margin (e.g., Fig. 2). The Valparaiso Moraine wraps around the southern end of Lake Michigan, extending into Michigan and Wisconsin; and in Indiana, the moraine forms the sub-continental drainage divide between the St. Lawrence and Mississippi drainage systems. Set inside the Valparaiso Moraine are two other recessional moraines known as the Tinley and Lake Border Moraines. All three ridges were likely deposited in a short period of time around 14,000 ybp by successive and less extensive readvances (Fig. 5). Glacial lakes formed between the ice and the ridges as the glacier receded northwards, opening up the lake basin. Because the glaciers were in lake basins, they rested on fine-grained sediment well-lubricated with water, and this low-resistive state (Clarke 1987) likely aided the glaciers ability to respond quickly to variations in climatic conditions and/or glaciologic controls. These responses are illustrated in Figs. 2–4, where four different positions of the ice margin are illustrated. The dated phases are averages and simplifications. For example, the Glenwood phase has been interpreted to consist of two separate advances with a low-lake phase between them (Hansel et al. 1985). Figures 2–4 are designed to provide the reader with only an overview of late-glacial events.

When the Lake Michigan lobe of the Laurentide Ice Sheet occupied the lake basin, the Straits of Mackinac were blocked by ice. Glacial Lake Chicago was dammed by the glacier (hence the term: glacial lake) and the outlet


2
3
4
ice lake
Glenwood phase ~12,800 ^{14}C B.P.
Two Creeks phase ~11,900 ^{14}C B.P.
ice lake
Calumet phase ~11,500 ^{14}C B.P.
200 kilometers
ice lake
Chippewa phase ~9800 ^{14}C B.P.
Nipissing phase ~4500 ^{14}C B.P.

Figures 2–4.—Position of lake levels (phases) as controlled by ice margins. Note that lake phases are not drafted for the Lake Huron basin, other than for the Glenwood phase. Dates are averages and along with the figures are based on Hansel et al. (1985) and Eschman & Karrow (1985). Note that the ice margin fluctuated over hundreds of kilometers over relatively short periods of time.

was located on the lowest point of the drainage divide (Leverett 1897). During the Glenwood phase (Fig. 2), the Chicago outlet was active, with water flowing through the Sag and Des Plains channels. Once the glacier receded northwards enough to deglaciate the Straits of Mackinac or Indiana River lowlands, lake level dropped and was controlled by outlets to the northeast (Hansel et al. 1985). The Chicago outlet was abandoned at this time, and forests grew on the newly exposed lake plain between the Glenwood shoreline and the much lower lake of the Two Creeks phase (Fig. 2). The northeast outlets were glaciated once more during a readvance of the Lake Michigan lobe, causing the lake to rise to the Calumet level. The rising lake buried a forest at Two Creeks, Wisconsin (Broecker & Farrand 1963) and other woody material in the Chicago region (Hansel et al. 1985) and northwest Indiana (Schneider & Reshkin 1982; Schneider & Hansel 1990). The radiocarbon dates indicate flooding of the land started at about 11,800 ybp. The higher lake level is known as the Calumet phase, and the Chicago outlet was reoccupied (Fig. 3). By about 11,200 ybp the Lake Michigan lobe had begun to retreat northwards of the Straits of Mackinac, and Lakes Michigan and Huron were confluent. This lake is called glacial Lake Algonquin, and some contend that any evidence of it in the region was eroded by the subsequent mid-Holocene Nipissing high phase (Karrow 1980; Hansel et al. 1985). However, more recently Chrzastowski & Thompson (1994) and Capps et al. (2000) have described erosional scarps just below the Calumet level as evidence for an Algonquin beach in the region. With continued retreat of ice in southern Ontario, the North Bay outlet was exposed around 10,300 ybp (Larsen 1987). Ancestral Lake Michigan dropped to a low level known as the Chippewa low (Fig. 4), which may have been as much as 107 m below the modern lake level (Hough 1955). More recently, Coleman et al. (1994) have suggested only an ≈80 m lowering. At this time until the mid-Holocene, ancestral Lake Michigan drained through the North Bay outlet into the Ottawa River before entering the St. Lawrence east of Lake Ontario.

The distribution of the sediment deposited during ice recession was partly controlled by elevation. On Fig. 5, the diamond pattern indicates glacigenic sediment (tills, debris flows, sand and gravel, and ice-contact glacial lake sediment) of the Lake Border sequence (Tinley and Lake Border Moraines) and Valparaiso Megasequence (Brown et al. 1996). The Glenwood-age sediment consists of two main types. First, the most obvious landforms are the extensive spits that built across northwest Indiana by the westerly transport of sand by littoral currents. Although not shown on Fig. 5, Glenwood-age spits are prevalent in Illinois; and they indicate an easterly transport direction. The spits record migration of sand southward along both sides of the lake, focusing sediment to its southern end. The spits record a lake level between about 195–189 m suggesting that the Chicago outlet was slowly being eroded during Glenwood time. The second type of Glenwood sediment is fine-grained lacustrine sediment of laminated and massive silty-clay. This unit is mapped as part of the Lake Border sequence and consists of approximately 16 m of laminated clay, silt, and silty clay and fine-grained till over bedrock (Bleuer and Woodfield 1993; Brown & Thompson 1995; Brown et al. 1996).

There are no sediments mapped for the Two Creeks phase because the region was subaerially exposed at this time. It is during this time and the subsequent Chippewa phase that the region's rivers carved their valleys. This incision was in response to the lower lake level that increased the streams bed slope. Evidence for the low lake level is now beneath the lake. For example, divers off Chicago found a buried forest with oak stumps rooted in place beneath 25 m of water (Chrzastowski et al. 1991). Radiocarbon dates averaging 8300 ybp suggest that the lake had risen to that elevation by then and drowned the trees.

The next youngest sequence of sediment in the region is affiliated with the Calumet Phase. Two map units are shown on Fig. 5. Sand dunes form an arc parallel to, and south of, the Little Calumet River. On either side of the dunes, beach, lagoon, and shallow water, sand and mud is exposed at the surface today. The elevation of the lake was at approximately 189 m. Spits were also formed at this time, but are restricted to near the Illinois state line and further west. The Calumet-age sediment is grouped with the Glenwood dunes and littoral sediment as part of the Lake Michigan sequence because in the subsurface it is dif-

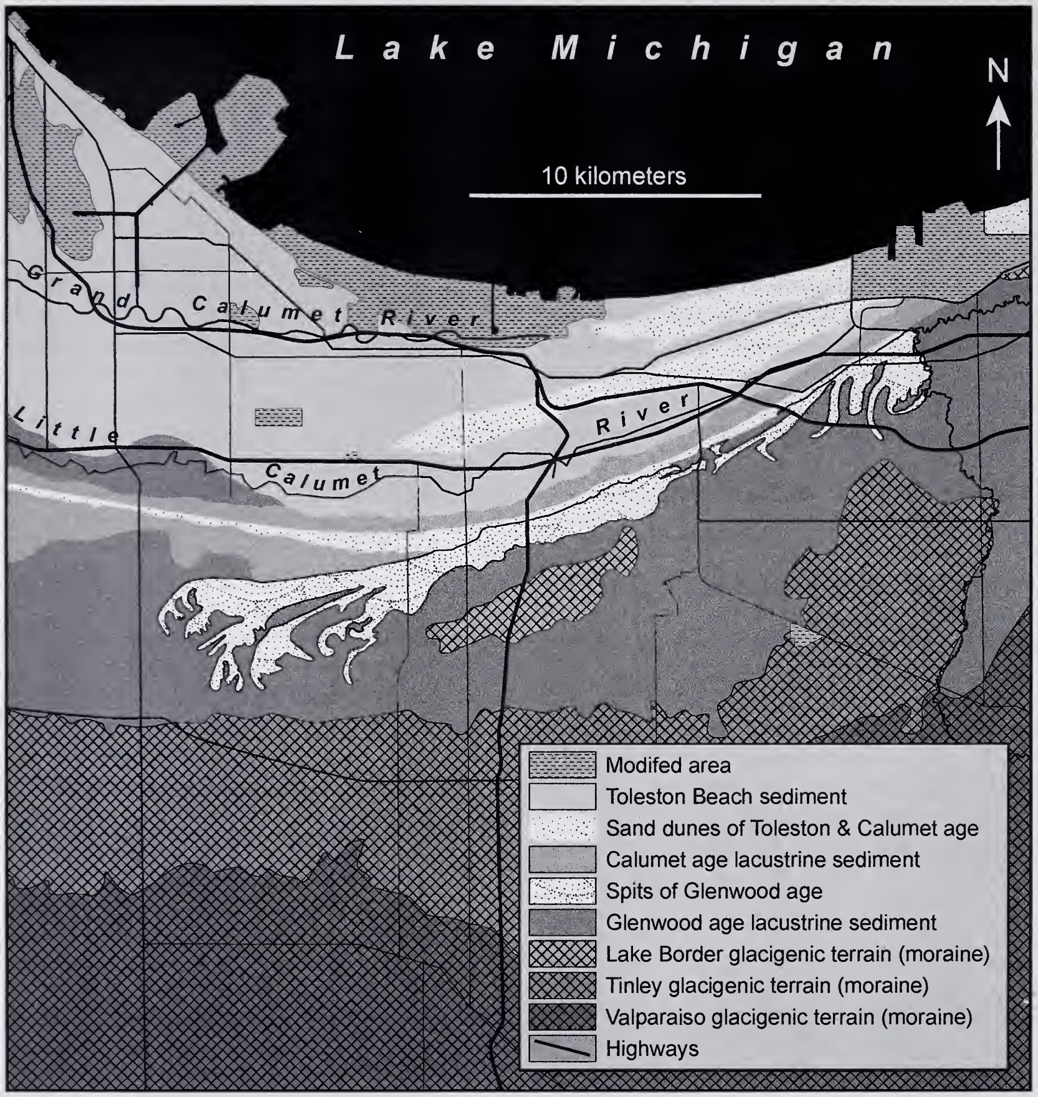

Lake Michigan
N
10 kilometers
Grand Calumet River
Little Calumet River
Modifed area
Toleston Beach sediment
Sand dunes of Toleston & Calumet age
Calumet age lacustrine sediment
Spits of Glenwood age
Glenwood age lacustrine sediment
Lake Border glacigenic terrain (moraine)
Tinley glacigenic terrain (moraine)
Valparaiso glacigenic terrain (moraine)
Highways

Figure 5.—Generalized Quaternary terrain map for northwest Indiana illustrating the inset relationship of moraines and beaches. As a general rule, the landscape becomes progressively younger from south to north. Modified from Brown et al. (1996).

ficult to differentiate between Glenwood and Calumet sediment (S.E. Brown pers. commun. 2002).

HOLOCENE CHANGES IN SOUTHERN LAKE MICHIGAN

Previously, the fluctuations in glacial Lake Chicago were explained by fluctuations in the ice margin of the Lake Michigan lobe: but interestingly, after the Lake Michigan lobe had retreated well north of the Great Lakes, the effect of the ice sheet was still felt in the Lake Michigan basin. A time lag exists between deglaciation and when the Earth's crust has reached its equilibrium elevation once the ice sheet load had been removed (slow isostatic rebound). As mentioned earlier for the Two Creeks phase, during the Chippewa phase, the outlet for the Great Lakes was the North Bay outlet rather than the modern outlet at Port Huron. During the Holocene, the North Bay outlet gradually rose causing Lakes Michigan and Huron to rise until they were confluent with Lake Superior (Larsen 1985). Lake

Michigan continued to rise until it reached two peaks at approximately 5300 (Larsen 1994) and 4700 ybp (Baedke & Thompson 2000) known as the Nipissing I and II high phases, respectively (Fig. 4). During the Nipissing phase the North Bay, Sag channel outlet (Chicago outlet), and Port Huron outlets were simultaneously active (Lewis 1969, 1970). With continued isostatic rebound, the North Bay outlet was abandoned; and there may have been a rapid drop in lake level that could be attributed to incision of the Port Huron outlet (Baedke & Thompson 2000). At around 2600 ybp the Sag channel was abandoned (Chrzastowski & Thompson 1992) leaving the Port Huron outlet as the sole outlet.

Since about 6300 ybp (Thompson & Baedke 1997), when the lake rose above the modern lake level from the Chippewa low to the Nipissing high, the 700 km^2 Toleston Beach began forming. A lake level curve going back to 4700 ybp was reconstructed based on the elevation of foreshore gravel deposits in beach ridges from the Lake Michigan basin since the Nipissing high (Baedke & Thompson 2000). Beach ridges record the high elevation of fluctuations in lake level, thus the curve (Fig. 6) is a smoothed record of high lake levels from the last 4700 years. It is interesting to note that Thompson (1992) and Thompson & Baedke (1995, 1997) were able to determine three scales of lake level fluctuations. There are 25–35, 140–160, and 500–600 yr cycles with a lake level elevation change of 0.5–0.6, 0.8–0.9, and 1.8–3.7 m, respectively.

The Toleston Beach has prograded basinward since the Nipissing high, and incorporates the Little and Grand Calumet Rivers. On Fig. 5 the Toleston-age sediment is shown in lightest gray. Sand dunes are stippled and dominate the eastern side of the Toleston Beach. The southern band of parabolic dunes had developed by 3200 ybp and point eastwards, reflecting westerly air flow. The younger, northern band of dunes contain parabolic dunes that point southeast and southwards recording a transition to more northerly air flow (Thompson 1992). Westward of the sand dunes, the Toleston Beach widens to where it contains over 100 beach ridges (Thompson & Baedke 1997).

The evolution of the Little and Grand Calumet Rivers is illustrated in Figs. 7–10 and was the result of three factors: 1) relative topographic gradients perpendicular to the shoreline, 2) littoral transport of sand from the northwest after about 3000 ybp, and 3) fluctuations in lake level. Along the eastern part of Fig. 5 the relative slope of the land into the off-shore zone is steeper than at the lake plain further west in the southwest corner of the lake. As a result, aeolian processes dominated, and dunes rather than beach ridges developed on the eastern side of the Toleston Beach. Further west, the southwest corner of the lake acted as a depositional sink; and beach ridges developed with only minor sand dune development.

Initially, the source of sand for most of the beach ridges in the Toleston Beach was from glacial deposits along the Michigan coastline. Bluff recession would have been particularly active during the rise in lake level from the Chippewa low to the Nipissing high. Recently, Loope & Arbogast (2000) demonstrated that the age of perched sand dunes along the western coast of Lower Michigan corresponds with high stands of Lake Michigan (see Fig. 6). Therefore, during these short-lived high stands, bluff recession would also increase sand supply for littoral transport. The paleogeographic reconstruction of Fig. 7 corresponds in time to about the Nipissing II peak. The lake has flooded the Sag Channel and the Calumet lagoon formed behind the early Toleston beach. Since the Nipissing II high, there was only westerly transport of sand to the southern end of the lake where beach ridges developed. The easterly transport of the sand did not reach the region until after 3000 ybp because the Chicago outlet embayment was trapping sediment (Chrzastowski & Thompson 1992). Figure 8 reflects a lowering of the lake level with continued beach and dune development. Note that by this time spits are building out from Stoney Island in Illinois across the outlet embayment, and beginning to deflect the Little Calumet River eastwards.

As the Calumet River turns east, it is referred to as the Grand Calumet River. Thus the Grand Calumet River came into existence just after 2600 ybp when the Sag Channel was abandoned (Chrzastowski & Thompson 1992). At about 1500 ybp all barriers to the south- and eastward transport of sand were removed (Fig. 9); and a large baymouth bar formed by spit growth, trapping an embayment of Lake Michigan to form Lake Calu-

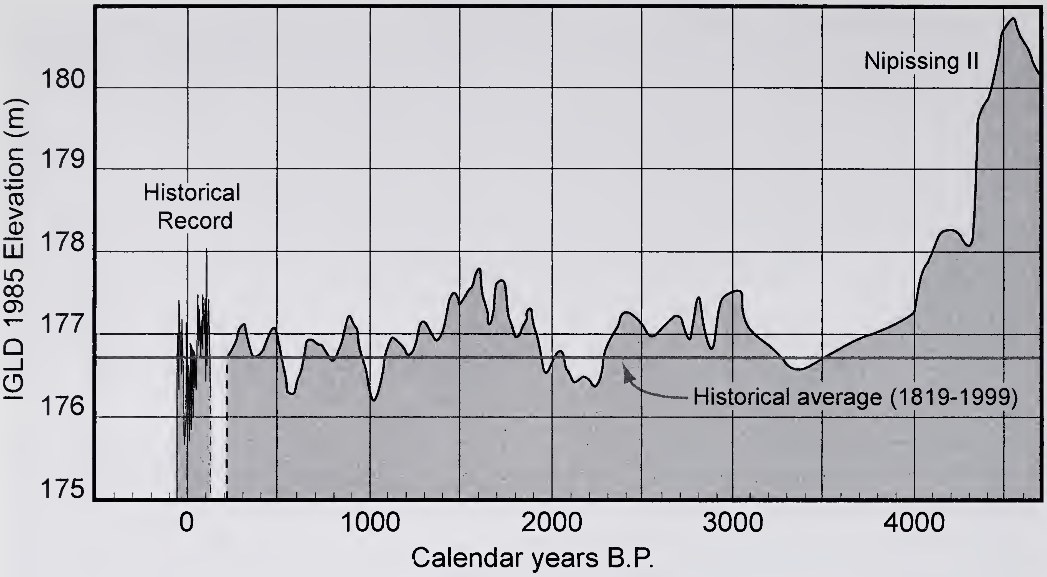


Figure 6.—A Fourier-smoothed lake level curve for Lake Michigan for the last 4700 years. Actual variations in lake level (peaks and troughs) are not shown. This curve combines data sets for around the Lake Michigan basin and illustrates the dramatic drop in lake level from the Nipissing II stage and multiple meter variations in lake level since 4000 ybp when the Toleston Beach was forming. IGLD–International Great Lake Datum. Modified from Baedke & Thompson (2000).

met. The Grand Calumet River entered Lake Calumet and was then continually deflected eastwards by spit growth at the mouth of the river. At about 1100 ybp continued spit growth had captured another part of ancestral Lake Michigan to form Wolf Lake (Fig. 10). The spit growth corresponds to high stages in Lake Michigan between 2000 and 1000 ybp (Fig. 6) and presumably increased sediment supply. The Toleston Beach continued to grow northward into the lake as beach ridges developed once every ≈30 years, while at the same time deflecting the Grand Calumet River further eastward. Development of the Toleston Beach had essentially stopped once European settlement in the area led to modification of the shoreline during the 19th and 20th centuries, although occasional beach ridges are still forming today on the eastern side of obstacles to littoral drift (Hunter et al. 1990). Shoreline positions for selected dates are superimposed on Fig. 10.

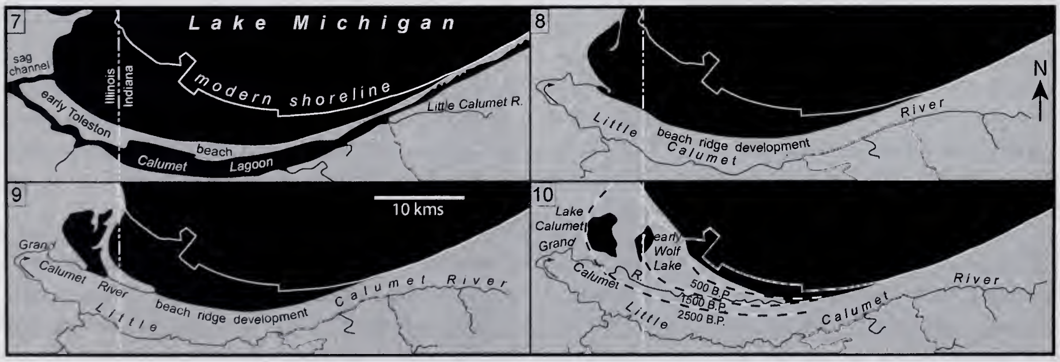


Figure 7–10.—The evolution of the Grand Calumet River was initiated by closing the Sag channel and deflection of the Little Calumet River eastwards by spit and beach ridge growth in the southwest corner of the lake. Figures modified from Chrzastowski & Thompson (1992) and Thompson (1992).

Sediments that underlie the region have been investigated by numerous researchers (Blueur & Woodfield 1993; Doss 1993; Brown & Thompson 1995; Brown et al. 1996). Beneath Lakes Calumet and Wolf, and the Grand Calumet River are 15–18.5 m of sand, gravel, and peat (Doss 1993) of the Lake Michigan sequence that is in turn underlain by finer grain sediment of the Lake Border sequence (Brown et al. 1996). Sand is the predominate sediment in the Toleston Beach, with minor amounts of gravel in the beach ridges; and organic material (peats) is found in swales between beach ridges and in the Calumet lagoon.

SUMMARY

The geology of the region is linked to the events of deglaciation and subsequent fluctuations in the levels of ancestral Lake Michigan. Glacial sediment of the Lake Border sequence and Valparaiso megasequence consists of tills and meltwater deposits from ice-marginal environments in the southern part of the region above 195 m elevation. Sometime around 14,000 ybp the glacier had receded northwards from Indiana and glacial Lake Chicago occupied the region in which fine-grained lacustrine sediment and spits were deposited during the Glenwood phase. Lake level dropped for about 500 years during the Two Creeks low phase until ice once again dammed the north end of the basin and the lake rose to the Calumet high phase, when another sandy beach with dunes formed. The lake dropped to the Chippewa low after final deglaciation of the Straits of Mackinac and North Bay outlet in Ontario. During the Chippewa phase when the lake was from 80–107 m lower than today, rivers eroded their valleys in the region in response to steeper streambed gradients. With the isostatic rise of the North Bay outlet, Lake Michigan became confluent with Lakes Superior and Huron during the Nipissing high; and the Port Huron outlet became the controlling outlet following abandonment of the North Bay and Chicago outlets. During the rise to the Nipissing high, the Toleston Beach began developing by 6300 ybp. The beach is dominated by sand dunes on its eastern edge and by more than 100 beach ridges further west where the Toleston Beach is up to 10 km wide. The Grand Calumet River developed once the Little Calumet River was deflected eastwards by spits at about 2600 ybp. Spits and beach ridges continued to grow until the end of the 19th century, which resulted in (1) capturing small embayments of Lake Michigan to form Calumet and Wolf Lakes, and (2) further deflecting of the Grand Calumet River eastward.

ACKNOWLEDGMENTS

This review paper has relied heavily upon the work by past researchers, in particular geologists affiliated with the Indiana and Illinois Geological Surveys. The forthcoming book *Calumet Area Beginnings* by Ken Schoon to be published by the Indiana University Press describes the history of the region since settlement and the affiliated changes to the landscape. Thanks to Ken who graciously allowed me access to a draft of his book when I was writing this article while on sabbatical leave in New Zealand. This review paper has benefited from the many discussions over the last eight years with Steve Brown of the Indiana Geological Survey who has provided information and maps in an efficient and unhesitating manner. An anonymous reviewer has improved the clarity of the manuscript. Lastly, I wish to acknowledge the Department of Geography at the University of Canterbury in New Zealand for support whilst I was writing this paper.

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WETLAND FLORA OF THE GRAND CALUMET RIVER IN NORTHWEST INDIANA: POTENTIAL IMPACTS OF SEDIMENT REMOVAL AND RECOMMENDATIONS FOR RESTORATION

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ABSTRACT. Northwestern Indiana supports unusually diverse floras. However, rapid industrialization and urbanization since the late 19th Century have changed much of the natural character of the wetlands along Grand Calumet River. Of more than 1400 species that occurred historically in the northwestern Indiana, 19 species were identified as extirpated species; and only 653 species, including 1 extirpated, 17 endangered, 14 threatened, and 18 rare species were documented during the recent surveys in the Grand Calumet River wetlands. Over 97% the wetlands along the Grand Calumet River were disturbed by fragmentation, infestation by alien species (120 of 653 species were alien), and anthropogenic disruption of ecosystem processes (e.g., fire suppression, draining, filling, and sedimentation). Among the wetlands along the Grand Calumet River, Roxanna Marsh, DuPont Tract, Clark & Pine East Nature Preserve, and Miller Woods were identified as high quality habitats with special needs of conservation. The proposed sediment dredging may cause direct physical damage to wetland floras, shoreline erosion along the stream banks, and "probable" drainage by deepening the riverbed. Restoration of ecosystem structure and function is needed to minimize such negative impacts that would potentially be incurred by the proposed sediment dredging.

Keywords: Wetland, flora, dredging, conservation, restoration

With its 14,000-year geologic history, northwestern Indiana natural areas support unusually diverse biological communities (Reshkin 1990). The diverse flora on the dune-and-swale complex on the southern shore of Lake Michigan has been noted by Cowles' (1899) bench-mark study, followed by Fuller (1935), Olson (1958), and Wilhelm (1990). Many factors caused drastic changes in species of the plant communities along the Grand Calumet River. The geomorphology of this river system has been altered significantly by human activities. The rivers have become straighter and narrower as a result of channelization. In addition, drainage and filling, along with industrial pollution of marshes and ponds adjacent to the river, altered local hydrology (Hiebert et al. 1986; Wilcox et al. 1986; Bowles 1990). This chapter discusses (1) pre-settlement and present-day wetland plant communities, (2) potential impacts of the proposed dredging project on wetland vegetation in the Grand Calumet River basin, and (3) restoration potentials of native wetland flora in conjunction with sediment removal.

NATIVE FLORA OF PRE-SETTLEMENT TIMES

Extirpated species.—Peattie (1930), in his publication *Flora of the Indiana Dunes*, estimated that 1400 plant species inhabited the Indiana Dunes area. Nineteen of these species have not been seen in Indiana since Peattie's sightings, and they have now been classified as extirpated species (species that had not been seen in Indiana for 50 years) by Aldrich et al. (1986). They are *Betula populifolia* (gray birch), *Carex scabrata*, *Corallorrhiza trifida* (coral root), *Gerardia pedicularia ambigens* (clammy false foxglove), *Hemicarpa drummondii*, *Hippuris vulgaris* (mare's tail), *Lechea stricta* (bush pinweed), *Lemna perpusilla* (least duckweed), *Linnaea borealis* (twin flower), *Lonicera canadensis* (American fly honeysuckle), *Oryzopsis pungens* (short-horned rice grass), *Panicum lucidum* (bog panic grass), *Psilocarya nitens* (bald rush), *Pyrola secunda* (one-sided shinleaf), *Scleria reticularis* (netted nut rush), *Shepherdia canadensis* (russet buffaloberry), *Trillium cernuum macranthum* (nodding trillium), and *Utricularia resupinata* (small purple bladderwort).

Historic plant community types.—Bacone et al. (1980) reconstructed the pre-settlement vegetation characteristics of northwestern Indiana by analyzing land survey records that were compiled between 1829 and 1834. The wetland community types recognized by this study are aquatic communities, marshes, swamps, bottomland forests, beach communities, and pannes.

Aquatic communities consist of macrophytes and phytoplankton in standing or running water. The 1829–1834 survey record noted *Polygonum* spp., *Nuphar advena*, and *Nymphaea tuberosa* as typical macrophytes (Bacone et al. 1980). Since European settlement, species composition of this community has been changed significantly by numerous human activities such as loading of nutrients, silts and other pollutants, alteration of local hydrology through channelization, drainage, and filling of the river and its adjacent wetlands.

Marshes are probably the most prominent plant community types along the Grand Calumet River. Marshes are open (non-forested) wetlands that are dominated by sedges and/or grasses communities (Bacone et al. 1980). On the wet end of the moisture gradient, sedge meadow is found directly adjacent to aquatic. At the other extreme, wet prairie overlaps with the borders of mesophytic prairies and savanna complex (Wilhelm 1990). As is indicated by its name, sedge meadow is characterized by abundant sedges (Cyperaceae); wet prairies are dominated by grasses (Poaceae). Typical plant species in this community type include *Aster puniceus firmus*, *Bidens coronata tenuiloba*, *Carex aquatilis altior*, *Decodon verticillatus*, *Polygonum punctatum*, and *Scirpus acutus*. Historically, periodic fires—both natural and man-made—have been a crucial factor in maintaining marshes because fires prohibit the invasion of woody shrubs and trees. Since European settlement, however, most marshes have been heavily disturbed by drainage, by invasion of woody species facilitated by artificial fire suppression and by intentional or accidental introduction of alien species (Labus et al. 1999).

Shrub carr is a transitional wetland from marsh to swamp. Typical woody species include *Alnus* spp. and *Salix* spp. According to the 1829–1834 survey record, woody species (e.g., *Populus tremuloides*, and *Populus grandidentata*) were less abundant in pre-settlement than the present times (Bacone et al. 1980). However, significant alterations in the level of the water table, and a long-lasting policy of fire suppression, have resulted in significant invasion of overgrown shrubs into marshes, sedge meadows and wet prairies (Wilcox et al. 1986).

Swamps are forested wetlands where the water level is maintained near the surface of the substrate by ground water or by rain (Wilhelm 1990). In the land survey records, the swamps in northwestern Indiana were classified into three major types. Coniferous swamps occurred only in dune-swale systems, and were dominated by *Pinus banksiana* and *Thuja occidentalis*. Timbered swamps, now classified as green ash (*Fraxinus pennsylvanica subintegerrima*) swamps, are inhabited by *Populus deltoides*, *Platanus occidentalis*, *Fraxinus nigra*, *Acer saccharinum*, and *Ulmus* spp. This type of swamp occurred along the Kankakee River. Extensive draining and logging in this century has destroyed much of this community. The species composition of these two community types is quite similar. Shared species include *Alnus rugosa americana* and *Salix* spp. This type of swamp, like the shrub carrs, has become more common than during pre-settlement times as a result of long-term drainage and fire suppression (Bacone et al. 1980).

Bottomland forests consist of several woody strata underlain by herbaceous cover, and they are located along the stream banks and are characterized by annual deposition of silt during flooding. Major canopy species in these forests include *Acer negundo*, *Acer saccharinum, Platanus occidentalis*, *Salix nigra*, *Ulmus americana*, and *Ulmus rubra*. Small, scattered patches of bottomland forest still occur today, although most of these have been heavily disturbed (Bacone et al. 1980; Wilhelm 1990).

Beach communities are narrow specialized strips adjacent to the littoral zone of the lakeshore, and they are dominated by *Ammophila breviligulata* (Cowles 1899; Wilhelm 1990; Poulson 1999). Pannes are moist interdunal depressions in calcareous sands on the leeside of dune, containing such species as *Aster ptarmicoides* and *Carex* spp. (Hiebert et al. 1986; Wilcox & Simonin 1987; Wilhelm 1990).

Table 1.—Eleven natural plant communities listed by Bowles et al. (1990) in Indiana Dunes National Lakeshore. Wetland types are signified by *italics*.

Community	Characteristics
Beach/Foredune	Wave actions and sandy substrate Annuals and rhizomatous perennial plants
Dune complex	Cycle of sand erosion in steep topography & blow-outs
Sand savanna	Dominant presettlement plant community type on irregular dune topography Open dune conditions with frequent fires
Sand prairie	Flat topography with frequent burns
Upland forest	Protected from intense fires (e.g., dune hollow and ravine slopes) Occasional ground fires
Forested Fen	Calcareous peat soils Relict boreal community Structure affected by fire and water table
Graminoid fen	Calcareous peat soils Boreal and prairie affinities Open conditions with frequent fires and high water table
Forested bog	Acid peat soils Relict boreal community High species diversity in openings and pools
Flatwoods	Wet mineral soils or seepages with high species diversity
Graminoid wetlands	Complex of fen and marsh in interdunal areas High water tables and frequent fires

EXISTING WETLAND PLANT COMMUNITIES

Recent vegetation survey and classification.—Bowles et al. (1990) listed 10 natural communities within the boundary of Indiana Dunes National Lakeshore (INDU). Six of these communities are considered wetland communities (Table 1). These communities include beach, forested fens, graminoid fens, forested bogs, flatwoods, and graminoid wetlands. Wilhelm (1990) also described 11 community types along the gradients of moisture and arborescent development. Among these communities, swamp complex, bog, marsh complex bottomland, and beach are considered as wetland communities. Wilhelm's (1990) list of vascular plants in the Miller Woods area, along with the species list compiled by Peloquin & O'Brien (1990), provides invaluable information on the floristic compositions of wetlands adjacent to the Grand Calumet River.

Natural communities in Lake, LaPorte and Porter Counties, excluding those found at INDU, were surveyed by Kurz et al. (1978). In this inventory, a total of 258 potential natural areas (PNA) was identified. These PNAs were then placed into three categories. Natural areas are of statewide significance, whereas notable areas are those which do not meet the criteria established for natural areas but do have considerable importance for education, research, and recreation. The third category, eliminated areas, consists of areas that still retain some traces of natural characters but which have been so severely disturbed that it is highly unlikely that they will recover the functions or structure of undisturbed natural areas. Kurz et al. (1978) also listed a total of 49 natural community types, including 26 aquatic and wetland types, that they had observed in the northwestern Indiana (Table 2). In Lake County, a total of 38 wetlands were identified, and seven of them were found adjacent to the Grand Calumet River. These wetlands were located in the DuPont tract, in the Ivanhoe Nature Preserve and in the Clark and Pine Nature Preserve (Fig. 1). Of the seven wetlands, three were placed in the natural area category, one was in the notable category, and three were in the eliminated category. In addition, an environmental assessment report that was submitted by the TAMS Consultants, Inc. (Mierzwa et al. 1991) for the Illinois-Indiana regional airport project, updated the lists of plant species for the DuPont tract, and for the Clark and Pine nature preserve.

Recent vegetation classification systems.—Concurrent use of different classification systems for the same natural areas (e.g., Kurz et al. 1978; Bowles 1990; Wilhelm 1990) often causes a great deal of confusion because (1) different terms are used to refer to the same community type, (2) similar terms are used for different communities, and/or (3) the borders between community categories are delineated differently. To reduce such confusion, a standardized classification system is proposed, based on the classification scheme of Indiana Department of Natural Resources (Table 3). In this table, for example, Wilhelm's (1990) "marsh complex" is separated into marsh, fen and sedge meadow. The "wet prairie" is a part of "marsh complex" in the Wilhelm's classification, but the proposed classification places it in the category of "prairie." In addition, "hydromesophytic forest" is a part of Wilhelm's "swamp complex," but it is placed the categories of "forest" and "shrub swamp" in the proposed classification system.

Special conservation needs.—Among the riparian wetlands of the Grand Calumet River, Roxanna marsh, DuPont tract, Clark & Pine East Nature Preserve (also known as Bongi Pond), and Grand Calumet Lagoons are especially in need of conservation because they are considered as high quality habitats for endangered, threatened and/or rare animals and plants. After a compilation of the existing plant species records (Wilhelm 1990; Mierzwa et al. 1991; IDNR unpubl.), 653 plant species (533 natives and 120 aliens) were found in DuPont tract, Clark & Pine East, and Miller Woods (Appendix). These species included 1 extirpated species (never found in its historical sites for last 50 years), 17 endangered species (inhabit between 1–5 extant sites), threatened species (inhabit between 6–10 sites), and 18 rare species (inhabit between 11–20 sites) (Aldrich et al. 1986; IDNR unpubl.).

Roxanna marsh is a severely degraded riparian wetland that is located where the Grand Calumet River intersects Route 41 in Hammond (Fig. 1). There has been no systematic survey for plant species or community types in this area. According to the author's visual

Table 2.—Forty-nine plant community types of Indiana coastal zone listed by Kurz et al. (1978). Wetland types are signified by *italics.*

Community type
Forest
Dry-mesic upland forest
Mesic upland forest
Wet-mesic upland forest
Dry dune forest
Dry-mesic dune forest
Mesic floodplain forest
Wet-mesic floodplain forest
Wet floodplain forest
Flatwoods
Prairie
Dry-mesic prairie
Mesic prairie
Wet-mesic prairie
Wet prairie
Dry sand prairie
Dry-mesic sand prairie
Mesic sand prairie
Wet-mesic sand prairie
Wet sand prairie
Glacial drift hill prairie
Gravel hill prairie
Sand hill (dune) prairie
Shrub prairie
Savanna
Dry-mesic savanna
Mesic savanna
Dry sand savanna
Dry-mesic sand savanna
Mesic sand savanna
Aquatic
Perennial stream
Lake
Pond
Marsh
Shrub swamp
Graminoid bog
Low shrub bog
Tall shrub bog
Forested bog
Calcareous floating mat
Graminoid fen
Low shrub fen
Tall shrub fen
Forested fen
Sedge meadow
Panne
Seep
Calcareous seep
Sand seep
Spring
Primary
Beach
Foredune/Blowout

Table 3.—Synthesized wetland plant community types under the classification scheme of the Indiana Department of Natural Resources. * = Wetland communities classified by Wilhelm (1990). ** = Wetland Communities classified by Bowles et al. (1990).

Communities by Kurz et al. (1978)	Communities by Bowles et al. (1990) and Wilhelm (1990)
Wet-mesic floodplain forest Wet floodplain forest	Bottomland forest* Hydromesophytic forest in the Swamp Complex*
Flatwoods	Flatwoods in the Swamp Complex* Flatwoods**
Wet-mesic prairie Wet prairie Wet-mesic sand prairie Wet sand prairie	Mesophytic prairie* Wet prairie of in the Marsh Complex* Graminoid wetlands**
Perennial stream Lake Pond	Aquatic*
Marsh	Marsh in the Marsh Complex* Graminoid wetlands**
Shrub swamp	Hydromesophytic forest and conifer swamp in the Swamp Complex*
Graminoid bog Low shrub bog Tall shrub bog Forested bog Calcareous floating mat	Bog* Forested bog** Graminoid wetlands**
Graminoid fen Low shrub fen Tall shrub fen Forested fen	Fen in the Marsh Complex* Forested fen** Graminoid fen**
Sedge meadow	Sedge meadow in the Marsh Complex* Graminoid wetlands**
Panne	Panne*
Seep Calcareous seep Sand seep Spring	Flatwoods**

inspection, the entire area was infested by undesirable species (alien, invasive, or both) such as *Lythrum salicaria*, *Phragmites communis*, *Typha angustifolia*, and *T. latifolia*. Several woody species (e.g., *Acer negundo*, *Populus deltoides*, and *Salix* spp.) have also invaded the wetland from adjacent riverbanks or woodlands. All of these species have very little or no value as elements of natural communities (Wilhelm 1990), and thus restoration of native vegetation is urgent in this area. Marsh, sedge meadow, and wet prairie are beneficial models for restoration because these were probably the most common wetland community types in the region's pre-settlement landscape. Their abundance has since been decreased significantly. The introduction of several species has been suggested for restoring marsh, sedge meadow, and wet prairie (Table 4; Wilhelm 1990).

After restoration of any of the above wetlands, periodic fires would be necessary to discourage the invasion of shrubs and trees (Henderson & Long 1984). Wet flood plain forest is very commonly found in the riparian community in the flood plains of streams and riv-

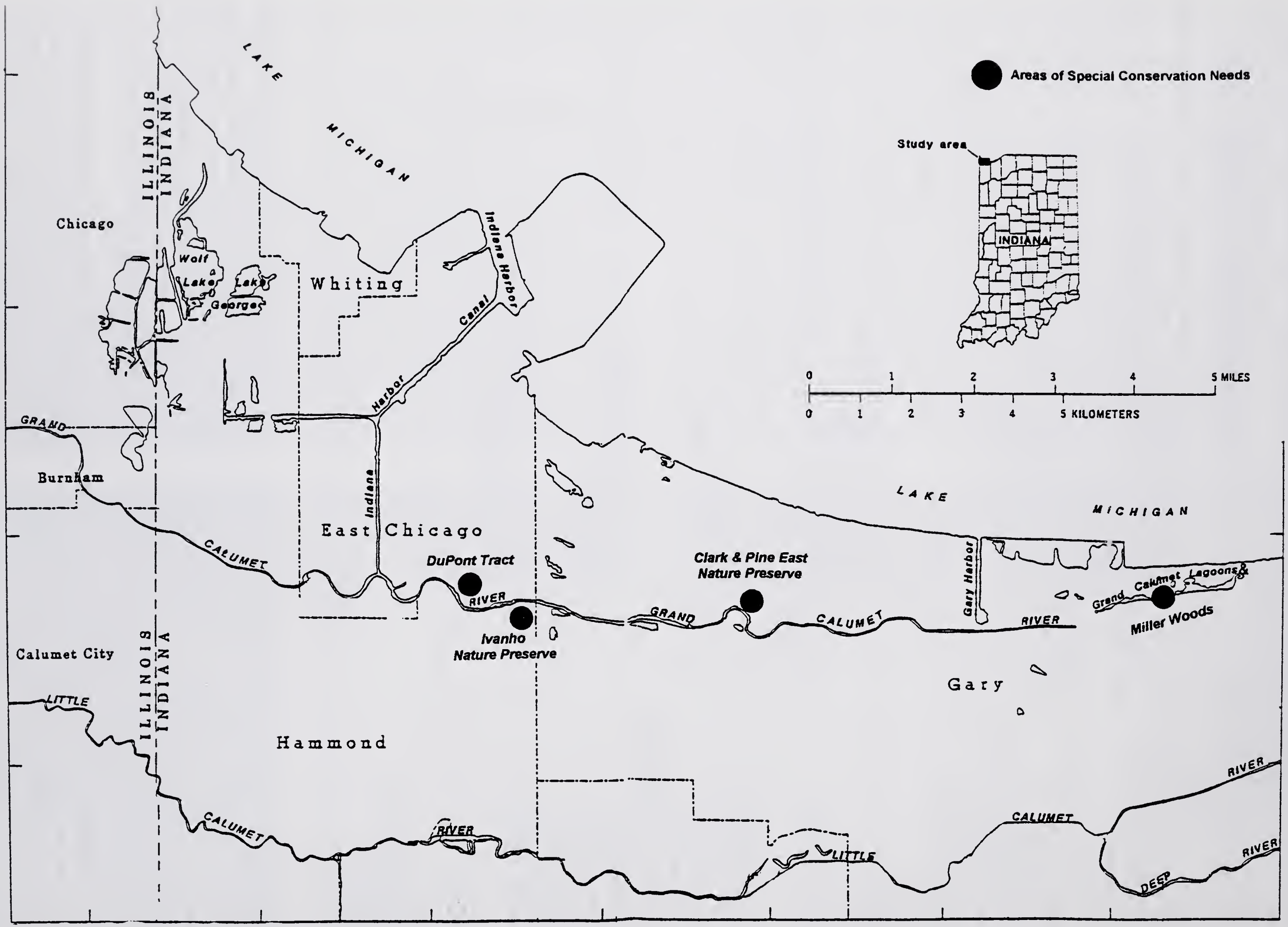

Figure 1.—Natural areas with special conservation needs along the Grand Calumet River in northwest Indiana. The dark circles indicate "Areas of Special Conservation Needs."

ers, so it may serve as a model of restoration for Roxanna Marsh. According to Wilhelm (1990), the following plants are typical of wet flood plain forest: *Acer saccharinum* (silver maple), *Cardamine bulbosa* (smooth spring cress), *Carex amphibola turgida* (gray sedge), *Carya laciniosa* (big shellbark hickory), *Chaerophyllum procumbens* (wild chevil), *Floerkea proserpinacoides* (false mermaid), *Fraxinus pennsylvanica* (green ash), *Populus deltoides* (cottonwood), *Salix nigra* (black willow), and *Viola striata* (striped white violet). Among the suggested species for wet floodplain forest restoration are highly invasive shrubs (e.g., *Populus deltoides* and *Salix nigra*) that produce quantities of seeds or that exhibit rapid vegetative growth. Periodic fires may be necessary to prevent over-growth of these species.

DuPont tract, owned by DuPont Chemical Company, is located to the east of Cline Avenue in Hammond, Indiana (Fig. 1). Despite extensive industrial development during the 1950s and the 1970s, significant portions of classical "dune and swale systems" are preserved in this property. TAMS Consultants (Mierzwa et al. 1991) and IDNR (unpubl.) documented 240 vascular plant species (203 natives and 37 aliens) including 1 endangered, 2 threatened, and 4 rare species (Tables 5, 6, 7 and Appendix). Clark & Pine East Nature Preserve is located in the southeastern corner of the East Chicago-Gary Regional Airport property (Fig. 1). Like the DuPont tract, this area is a classical example of a dune and swale system. TAMS Consultants (Mierzwa et al. 1991) and IDNR records for the area (unpubl.) list 271 species (245 natives and 26 aliens) including 7 endangered, 4 threatened, and 7 rare species (Tables 5, 6, 7 and Appendix). Aggressive expansions of invasive species, both alien and native, pose serious threats to populations of native species in the Clark & Pine East Nature Preserve. The riverbanks in these natural areas are heavily infested with *Phragmites communis berlandieri*, *Lythrum salicaria*, and *Typha angustifolia*. Spread of these species is generally facilitated by their effective pollination systems, seed dispersal (mostly by wind), breeding systems (e.g., facultative apomixis) and, in many circumstances, rapid vegetative growth by "root-suckering" or "stem sprouts" (Baker 1986). These characteristics make this group of species very likely to continue expand aggressively in the wetlands of this tract, thereby out-competing native species. Forty alien species have already been found in the natural areas of DuPont and Clark and Pine East tracts. Most wetlands of the Grand Calumet Lagoons are located within the Miller Woods area, which is a part of INDU (Fig. 1). This is home to what probably is the best-preserved and most diverse flora in northwestern Indiana. *Potamogeton pulcher* (spotted pondweed), presumed to be an extirpated species, was found by Wilhelm (1990). Whilhelm (1990) also documented 555 species (453 natives and 102 aliens) including 12 endangered, 12 threatened, and 12 rare species (Tables 5, 6, 7 and Appendix).

POTENTIAL IMPACTS OF SEDIMENT REMOVAL

The U.S. Army Corps of Engineers (1997), after a comparison of 18 different methods for sediment treatment, recommended "mechanical dredging" with a closed bucket (often called a "clam-shell bucket"). Three potential impacts of the dredging operation on the Grand Calumet River riparian wetlands are possible. First, mechanical dredging may cause direct physical damages (e.g., trampling) to the riparian wetlands. Preparation of staging areas and an access road would inevitably remove some riparian vegetation. Physical damages could be critically disruptive if done in sensitive wetland habitats such as the DuPont tract, Clark & Pine East, and Miller Woods. Second, the removal of sediments would certainly deepen the riverbed, steepen the shores and eventually facilitate soil erosion on the stream-banks, and this would lower water quality. Third, local wetland hydrology could be modified by a deepening the river; i.e., deepening of the river bed may facilitate drainage from the adjacent wetlands, and this "probable" drainage may cause drastic changes in plant species composition (e.g., from *Carex* spp. to *Typha* spp.) as evidenced in the nearby Cowles Bog in the Indiana Dunes National Lakeshore (Wilcox & Simonin 1987). To minimize these impacts, I suggest the following considerations for the proposed sediment removal project in the Grand Calumet River and Indiana Harbor Ship Canal:

1. Any sediment removal project should aim to restore full ecosystem function and

Table 4.—Suggested species matrices for restoration of marsh, sedge meadow, and wet prairie along the Grand Calumet River (Wilhelm 1990).

Marsh
- *Aster puniceus firmus* (marsh aster)
- *Carex comosa* (bristle sedge)
- *C. haydenii* (long-scaled meadow sedge)
- *C. lacustris*
- *C. lanuginosa* (woolly sedge)
- *C. lasiocarpa americana* (narrow-leaved woolly sedge)
- *C. starwellii*
- *C. stricta* (meadow sedge)
- *C. tribuloides*
- *Decodon verticillatus* (swamp loosestrife)
- *Lysimachia thyrsiflora* (tufted loosestrife)
- *Polygonum hydropiperoides* (mild water pepper)
- *Potentilla palustris* (marsh cinqefoil)
- *Proserpinaca palustris crebra* (mermaid weed)
- *Rumex orbiculatus* (great water dock)
- *Scirpus acutus* (hard-stemmed bulrush)
- *S. validus creber* (great bulrush)
- *Scutellaria epilobiifolia* (marsh skullcap)
- *Sium suave* (water parsnip)

Sedge meadow
- *Aster junciformis* (rush aster)
- *Bidens comosa* (swamp tickseed)
- *Dryopteris thelyteris pubescens* (marsh shield fern)
- *Eupatorium perfoliatum* (common boneset)
- *Hypericum virginicum fraseri* (marsh St. John's wort)
- *Lycopus uniflorus* (northern bugle weed)
- *Mentha arvensis villosa* (wild mint)
- *Polygonum punctatum* (smartweed)
- *P. sagittatum* (arrow-leaved tear-thumb)

Wet prairie
- *Aletris farinosa* (colic root)
- *Cladium marsicoides* (twig rush)
- *Eleocharis melanocarpa* (black-fruited spike rush)
- *Gentiana crinita* (fringed gentian)
- *Juncus canadensis* (Canadian rush)
- *Ludwigia alternifolia* (seedbox)
- *Oxypolis rigidior* (cowbane)
- *Rubus hispidus obovalis* (swamp dewberry)
- *Sisyrinchium atlanticum* (eastern blue-eyed grass)
- *Spiranthes cernua* (nodding lady's tresses)

structure of the Grand Calumet River and its adjacent wetlands. The project should not be limited to the simple activity of "getting the dirt out." The river cannot attain full ecological functioning without having its riparian wetlands restored. Only removing the sediment will certainly waste resources. For this reason, it is critical that the proposed sediment dredging be accompanied by the restoration of riparian wetlands.

2. Physical damages to the wetland communities must be avoided, or at least minimized, during the sediment removal operation. Toward this end, the staging areas must be located as far as possible from the sensitive habitats, such as DuPont tract, Clark and Pine East Nature Preserve, and Miller Woods. The Roxanna Marsh area is an ideal candidate for a staging area, provided that the operation is not done during the breeding seasons for fish and wildlife. The area is considered to be severely degraded land. Such undesirable plants as *Typha* spp. and *Phragmites* spp. would be removed during the preparation of staging area. After sediment-removal operations, this area could be restored as wildlife habitat by establishing native plant communities such as sedge meadow or wet prairie.

3. Disposal sites for removed sediment should be located a safe distance from sensitive wetland habitats. Ecological feasibility of disposal at any proposed disposal site should be evaluated. Restoration of wetland ecosystems in the riparian lands (the areas immediately adjacent to the river) are crucial for establishing full ecological functions of the Grand Calumet River. Therefore, it is recommended that all riparian lands along the Grand Calumet River be excluded from the sediment disposal.

4. Stream-bank erosion should be prevented by the construction of appropriate anti-erosion structures. For example, BioLogs™ (long rolls of coconut fiber encased in coconut netting) may serve as submersible substrate to anchor native aquatic plants and create calm "eddies" that protect and enhance wildlife. These structures are commercially available, and they have been used successfully (e.g., marsh restoration in Hackensack Meadowlands, New Jersey; Driver 1993).

5. After removing the sediments, it is recommended that the riverbeds be lined with sand to make a gentle slope from the shores to the center. This approach has been used for stream bank stabilization (Abt et al. 1995). The gentle slopes not only prevent drastic bank erosion, but they also provide an important feeding habitat for wildlife because birds (especially wading birds and possibly other

Table 5.—Endangered plant species, as listed by Indiana Department of Natural Resources, in the wetlands of DuPont Tract, Clark & Pine Nature Preserve (C&P), and Miller Woods.

Species		Location		
Scientific name	Common name	DuPont	C&P	Miller
Agalinis purpurea	Purple foxglove		X	
Carex brunnescens sphaerostachya	Brown sedge		X	
Carex bushii	Long-scaled sedge		X	
Carex richardsonii	Prairie hummock sedge		X	
Eleocharis geniculata	Knee spike bush		X	X
Equisetum variegatum	Small scouring rush			X
Glyceria borealis	Northern manna grass			X
Juncus scripoides	Round-headed rush			X
Ludwigia sphaerocarpa deamii	Round-fruited loosestrife			X
Lycopus americana	Common water horehound	X	X	X
Panicum columnianum	Hemlock panic grass			X
Panicum dichotomiflorum	Knee grass			X
Polygonum hydropiperoides	Mild water pepper			X
Potamogeton robbinsii	Fern pondweed			X
Satureja arkansana	Dogmint			X
Scleria pauciflora caroliana	Few-flowered nut rush		X	
Talinum rugospermum	Fame flower			X

animals, too) favor gentle dish-shaped basins over steep cup-shaped ones (Smith et al. 1994).

6. To investigate the impact of the proposed sediment removal on the local hydrology and plant communities of adjacent wetlands, an experimental pilot dredging project is recommended.

THREATS AND RESTORATION POTENTIALS FOR WETLAND FLORA

Shuey (1996) listed three major threats to biodiversity in the southern shore of Lake Michigan as follows: (1) habitat fragmentation and natural land conversion, (2) infestation of exotic species and (3) anthropogenic disruption of ecosystem processes. Industrial and ur-

Table 6.—Threatened plant species, as listed by Indiana Department of Natural Resources, in the wetlands of DuPont Tract, Clark & Pine Nature Preserve (C&P), and Miller Woods.

Species		Location		
Scientific name	Common name	DuPont	C&P	Miller
Arenaria stricta	Stiff sandwort			X
Aristata intermedia	False arrow feather		X	X
Aster ptarmicoides	Stiff aster		X	X
Cakile edentula	Sea rocket			X
Carex aurea	Golden sedge	X	X	X
Carex bebbi	Bebb's oval sedge	X		
Carex garberi	False golden sedge			X
Cirsium picheri	Dune thistle			X
Eriophorum angustifolium	Narrow-leaved cotton grass		X	
Juncus pelocarpus	Brown-fruited rush			X
Lathyrus orchtoleucus	Pale vetchling			X
Myriophyllum verticullatum pentinatum	Whorled water milfoil			X
Polygonella articulata	Jointweed			X
Utricularia cornuta	Horned bladderwort			X

Table 7.—Rare plant species, as listed by Indiana Department of Natural Resources, in the wetlands of DuPont Tract, Clark & Pine Nature Preserve (C&P), and Miller Woods.

Species		Location		
Scientific name	Common name	DuPont	C&P	Miller
Aralia nudicularis	Wild sarsaparilla		X	X
Arctostaphylos uva-ursi coatilis	Arctic bearberry		X	X
Aster borealis	Rush aster			X
Baptisia leucantha	White wild indigo	X		X
Betula papyrifera	Paper birch	X	X	
Catalpa speciosa	Northern catalpa	X		
Cypripedium caleolus parviflorum	Small yellow lady's slipper		X	
Diervilla lonicera	Dwarf honeysuckle			X
Drosera intermedia	Narrow-leaved sundew			X
Hypericum kalmianum	Kalm's St. John's wort	X	X	
Liparis loeselii	Green twayblade		X	X
Pinus banksiana	Jack pine			X
Pogonia ophioglossoides	Snake-mouth orchid			X
Potamogeton pusillus	Small pondweed			X
Rhynchospora macrostachya	Horned beak rush			X
Solidago ptarmicoides	Prairie golden rod			X
Tofieldia glutinosa	False asphodel		X	

ban development not only eliminated most natural habitats but also fragmented remaining patches of natural lands. Habitat fragmentation has several negative effects. Decline of species richness in isolated small habitats is a classic example of island biogeography that is supported by numerous filed evidences (e.g., Schonewald-Cox 1983; Newmark 1995). As distance between habitat patches increases, recolonization following local population crash becomes less likely, which can ultimately lead to the regional collapse and extirpation of highly-sensitive species such as Karner blue butterfly (*Lycaeides melissa samuelis*), an endangered species as listed by U.S. Endangered Species Act, on the southern shore of Lake Michigan (Shuey 1996; Knutson et al. 1999). Fragmentation may also disrupt the life cycles of species with complex habitat requirements, such as species that may require wetlands for reproduction but uplands for foraging. Edge effects from fragmentation are also problematic. Severe fragmentation increases vulnerability to invasion of exotic species into core natural areas (Shuey 1996) and unnatural predation from disturbance-adapted predators, such as raccoons (*Procyon lotor*), skunks (*Spilogale* spp.), and blue jays (*Cyanocitta cristata*) (Yahner 1988; Shuey 1996).

Exotic species overrun native habitats, often eliminating entire flora on the southern shore of Lake Michigan. Severe land disturbance by physical forces (Bowles et al. 1990; Shuey 1996), nutrient enrichment (Inouye & Tilman 1995), and altered hydrology (Wilcox et al. 1986) generally favor exotic species over native plants. The wetlands on the southern shore of Lake Michigan, as well as entire Midwestern U.S., are overrun by *Phragmites communis* (giant reeds), *Typha angustifolia* (narrow-leaf cattail), *Lythrum salicaria* (purple loosestrife), and an exotic genotype of *Phalaris arundinacea* (reed canary grass), whereas the upland fields and oak-savannas are overrun by *Robinia pseudoacacia* (black locust), *Rosa multiflora* (multiflora rose), *Ulmus pumila* (Siberian elm), *Lonicera japonica* (Japanese honeysuckle), *Rhamnus* spp. (buckthorns), *Melilotus* spp. (sweet clovers), *Coronilla varia* (crown vetch), *Allaria officinalis* (garlic mustard), and other exotic plants (Bowles et al. 1990; Wilhelm 1990; Shuey 1996; Choi & Pavlovic 1998; Peloquin & Hiebert 1999).

Closely related to the impact of habitat loss is the elimination or alteration of ecosystem processes. The ecological communities of the southern shore of Lake Michigan were among the most dynamic in the midwestern U.S., created and maintained by wildfires, hydrological fluctuations, and onshore transport of sands and sediments. Wildfires originally played a critical role in maintaining open habitats in the area. Habitats such as oak-savanna, tall-grass prairie, and sedge meadow have been maintained by periodic wildfires that discouraged the invasions by woody plants such as *Robinia pseudoacacia*, *Sassafras albidum* (sassafras), *Populus deltoides* (cottonwoods), *Cornus* spp. (dogwoods), and *Salix* spp. (willows) and the over-growth and over-reproduction of oaks (*Quercus* spp.) (Taylor 1990; Wilhelm 1990; Choi & Pavlovic 1998). Unfortunately, modern culture has traditionally abhorred wildfires because of the perceived destructive nature of fire, and this mentality led to artificial suppression of wildfires for more than a century. Without the influence of fire, open habitats such as oak-savannas have succeeded to oak forests with full closure of their canopies now interrupting penetration of sunlight to ground layer. This transformation of community types has caused significant decline of *Lupinus perennis* (wild lupine) which favors openings in oak-savannas, and the decline of *L. perennis* lead to the endangerment of the endemic Karner blue butterfly whose larvae forage exclusively on the leaves of lupines (Grundel et al. 1998).

Historically, fluctuations of the local water table played a critical role in maintaining lakeplain and marsh communities. The swales collect water from well-drained soils of ridges as well as from underground. Therefore, water levels in the swales are dependents of aboveground runoff, seepage from sandy ridges, underground water table depths, short term fluctuations of Lake Michigan water level and the long term retreat of the lake (Thompson 1992; Chrzastowski et al. 1994; Brown 1997; Labus et al. 1999). Periodic episodes of elevated water tables re-set succession and maintain the highly productive herb-dominated systems. Many rare species, such as *Utriculata* spp. (bladderworts), and *Cypripedium* spp. (lady's slippers), in the lakeplain ponds are annuals. These annuals are dormant until a favorable moisture condition stimulates germination. When this happens, they quickly reach maturity and set seed before drought or inundation ensues. Alteration of ground water regime has disrupted these delicate cycles (Keddy 1990). On the other hand, *Carex* spp., *Scirpus* spp., and *Juncus* spp. (sedges and rushes) were dominant perennials in the lakeplain wetlands because they could tolerate seasonal droughts better than other perennials such as cattails. However, extensive runoff from impervious land surfaces (e.g., highways, parking lots, and residential discharge) inundated the soil all year long causing massive invasions of *Typha*, followed by *Phragmites*, *Lythrum*, and *Phalaris* (Wilcox et al. 1986; Choi 2001).

The onshore deposition of sandy sediments has been responsible for the formation of dunes and beaches in the southern shore of Lake Michigan. Sand grains from eroding banks and tributary mouths are carried by onshore currents and winds and accrete to form dunes, beaches, sandbars, and spits that shelter the pannes (wetlands with highly alkaline water) in intradunal depressions (Thomson 1992; Chrzastowski et al. 1994). Today, lakefront development (e.g., marinas, piers, and concrete walkways) in Chicago in Illinois, and Hammond and Gary in Indiana interrupts much of the sediment movements and depositions along the shoreline. These interruptions arrest the formation of new beaches, dunes, swales, and pannes (Shuey 1996; Labus et al. 1999).

Choi (2001) identified 34,771 ha of wetlands (from the National Wetland Inventory (NWI) - a Geographic Information System (GIS) database) along the Grand Calumet River. Of these wetlands, only 197 ha (0.6%) were high quality and 657 ha (1.9%) are restorable to natural conditions. Much of the others (33,917 ha, 97.5%) are also restorable to certain conditions; however, limited technology, high financial cost, and social and political ramifications (i.e., conflicts between economic growth and environmental conservation) only solidify the unlikelihood of restoration in this highly industrialized region (PAHLS 1993).

Appendix.—Check list of plant species in DuPont tract (DT), Clark and Pine East Nature Preserve (CP), and Miller Woods (MW). Three classes of protection (status) by State of Indiana, extirpated (Ex), endangered (E), threatened (T), rare (R), and watch list (W) are indicated. Alien species (A) are also indicated. Data compiled from Wilhelm (1990), Mierzwa et al. (1991), and unpublished data from the Indiana Department of Natural Resources.

Scientific name	Common name	DT	CP	MW	Status
Abutilon theophrasti	Velvetleaf			X	A
Acer negundo	Boxelder	X		X	
Acer platanoides	Norway maple			X	A
Acer rubrum	Red maple		X	X	
Acer saccharinum	Silver maple	X	X	X	
Achillia millefolium	Yarrow	X		X	A
Agalinis purpurea	Purple false foxglove	X	X	X	
Agalinis skinneriana	Pale false foxglove		X		E
Agalinis tenuifolia	Slender false foxglove			X	
Agropyron repens	Quack grass			X	A
Agropyron smithii	Western wheat grass			X	A
Agropyron trachycaulum unilaterale	Bearded wheat grass		X	X	
Agrostis alba	Redtop	X	X	X	A
Agrostis hymalis	Tickle grass			X	
Ailanthus altissima	Tree of heaven	X			A
Alestris farinosa	Colic root			X	
Alisma subcordatum	Common water plantain		X	X	
Alisma trivale	Large-flowered water plantain	X		X	
Allaria officinalis	Garlic mustard			X	A
Allium cernuum	Nodding wild onion			X	
Althaea rosea	Hollyhock	X			A
Ambrosia artemisiifolia elatior	Common ragweed	X		X	
Ambrosia psilostachya coronopifolia	Western ragweed			X	A
Ambrosia trifida	Giant ragweed	X	X	X	
Amelanchier arborea	Serviceberry		X		
Amelanchier interior	Inland shadbush			X	
Amelanchier laevis	Allegheny shadbush			X	
Ammophila breviligulata	Merram grass			X	W
Amorpha canescens	Lead plant	X			
Amphicarpa bracteata	Upland hog peanut			X	
Andropogon gerardii	Big bluestem grass	X	X	X	
Anemone canadensis	Meadow anemone			X	
Anemone cylindrica	Thimbleweed	X	X	X	
Antennaria neglecta	Cat's foot		X		
Antennaria plantaginifolia	Pussy toes		X	X	
Anthriscus caucalis	Bur chervil			X	
Apios americana	Ground nut	X		X	
Apocynum androsemifolium	Spreading dogbane			X	
Apocynum cannabinum	Indian hemp	X	X	X	
Apocynum sibiricum	Prairie Indian hemp	X	X	X	
Aquilegia canadensis	Wild columbine	X	X		
Arabis lyrata	Sand cress	X	X	X	
Aralia nudicaulis	Wild sarsaparilla		X	X	R
Arctostaphylos uva-ursi coatilis	Arctic bearberry	X	X	X	R
Arenaria lateriflora	Wood sandwort	X			
Arenaria serpyllifolia	Thyme-leaved sandwort			X	A
Arenaria stricta	Stiff sandwort			X	T
Aristata intermedia	False arrow feather		X	X	T
Aristata oligantha	Plains three-awn grass			X	A
Aristata purpurascens	Arrow feather			X	A
Aronia melanocarpa	Black chokeberry			X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Aronia prunifolia	Chokeberry		X	X	
Artemisia caudata	Beach wormwood	X	X	X	
Artemesia vulgaris	Mugwort			X	A
Asclepias amplexicaulis	Sand milkweed			X	
Ascelpias incarnata	Swamp milkweed	X	X	X	
Ascelpias syriaca	Common milkweed	X	X	X	
Asclepias tuberosa	Butterfly weed	X	X	X	
Asclepias verticillata	Whorled milkweed	X	X	X	
Asclepias viridiflora	Short green milkweed			X	
Asparagus officinalis	Asparagus	X	X	X	A
Aster azureus	Sky-blue aster	X	X	X	
Aster borealis	Rush aster			X	R
Aster dumosus	Rice-button aster	X	X		
Aster ericoides	Heath aster	X		X	
Aster laevis	Smooth blue aster			X	
Aster lateriflorus	Side-flowering aster		X	X	
Aster liniariifolius	Flax-leaved aster			X	
Aster novae-angliae	New England aster		X	X	
Aster pilosus	Hairy aster			X	
Aster ptarmicoides	Stiff aster		X	X	T
Aster puniceus firmus	Shining aster			X	
Aster sagittifolius	Arrow-leaved aster			X	
Aster sagittifolius drummondii	Drummond's aster			X	
Aster simplex	Panicled aster	X	X	X	
Aster umbellatus	Flat-top aster		X	X	
Aureolaria pedicularia ambigens	Clammy false foxglove			X	
Baptisia leucantha	White wild indigo	X		X	R
Babarea vulgaris	Yellow rocket			X	A
Betula papyrifera	Paper birch	X	X		R
Bidens cernua	Nodding bur marigold			X	
Bidens comosa	Swamp tickseed			X	
Bidens coronata	Tall swamp marigold		X	X	
Boehmeria cyclindrica	False nettle	X		X	
Boltonia latisquama recognita	False aster			X	
Bromus inermis	Hungarian brome			X	A
Bromus japonicus	Japanese chess			X	A
Bromus kalmii	Prairie brome		X	X	
Bromus tectorum	Downy brome	X		X	A
Bulbostylis capillaris	Hair sedge			X	
Cacalia plantaginea	Prairie Indian plantain			X	
Cakile edentula	Sea rocket			X	T
Calamagrostis canadensis	Blue joint grass	X	X	X	
Calamovilfa longifolia	Sand reed	X	X	X	
Camassia scilloides	Wild hyacinth			X	
Campanula aparinoides	Marsh bellflower	X	X	X	
Campanula rotundifolia	Harebell		X		
Campanula uliginosa	Marsh bellflower	X			
Cannabis sativa	Hemp		X		A
Capsella bursa-pastoris	Shepherd's purse			X	A
Carduus nutans	Musk thistle	X			A
Carex alata	Winged oval sedge			X	R
Carex aurea	Golden sedge	X	X	X	T
Carex bebbii	Beb's oval sedge	X			T
Carex brevior	Plains oval sedge	X	X		
Carex buxbaumii	Dark-scaled sedge	X	X		

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Carex brunnescens sphaerostachya	Brown sedge		X		E
Carex bushii	Long-scaled green sedge		X		E
Carex comosa	Bristly sedge			X	
Carex crawei	Early fen sedge		X		T
Carex emoryi	Riverbank sedge			X	
Carex garberi	False golden sedge		X	X	T
Carex granularis	Pale sedge			X	
Carex haydenii	Long-scaled tussock sedge			X	
Carex hystrixina	Porcupine sedge		X		
Carex interia	Prairie star sedge			X	
Carex lanuginosa	Woolly sedge	X	X	X	
Carex muhlenbergii	Sand bracted sedge	X		X	
Carex pensylvanica	Common oak sedge	X		X	
Carex richardsonii	Prairie hummock sedge		X		E
Carex starwellii	Running marsh sedge	X		X	
Carex siccata	Running savanna sedge			X	
Carex stricta	Common tussock sedge	X	X	X	
Carex suberecta	Wedge-fruited oval sedge	X	X		
Carex tenera	Narrow-leaved oval sedge		X		
Carex tetanica	Common stiff sedge	X			
Carex tonsa	Smooth-fruited sedge			X	
Carex tribuloides	Awl-fruited oval sedge			X	
Carex umbellata	Early oak sedge	X	X	X	
Carex viridula	Green yellow sedge		X	X	
Carex vulpinoidea	Brown fox sedge		X		
Cassia fasciculata	Patridge pea			X	W
Cassia nictitans	Wild sensitive plant			X	
Castilleja coccinea	Indian paintbrush	X	X	X	
Catalpa speciosa	Northern catalpa	X			R
Ceanothus americanus	New Jesey tea	X		X	
Celastrus scandens	Climbing bittersweet	X	X		
Cenchrus longispinus	Sandbur	X		X	
Centaurium pulchellum	Showy centaury	X	X		A
Cephalanthus occidentalis	Buttonbush	X	X	X	
Chelone glabra	Turtlehead	X			A
Chenopoodium album	Lamb's quarters			X	A
Chenopodium leptophyllum	Narrow-leaved goosefoot			X	
Chenopodium standleyanum	Woodland goosefoot			X	
Cicuta bulbifera	Bulblet-bearing water hemlock			X	
Cinna arundinacea	Common wood reed	X	X		
Cirsium arvense	Field thistle		X	X	A
Cirsium discolor	Pasture thistle	X	X	X	
Circium muticum	Swamp thistle	X	X	X	
Cirsium pitcheri	Dune thistle			X	T
Cirsium vulgare	Bull thistle	X	X	X	A
Cladium maricoides	Twig rush	X	X	X	
Commandra umbellata	False toadflax	X		X	
Commelina communis	Common day flower	X			A
Commelina erecta deamiana	Narrow-leaved day flower			X	
Conium maculatum	Poison hemlock	X			A
Convolvulus arevensis	Field bindweed	X			A
Convolvulus sepium	Hedge bindweed	X		X	
Coreopsis lanceolata	Sand coreopsis	X	X	X	
Coreopsis palmata	Prairie coreopsis		X	X	
Coreopsis tripteris	Tall coreopsis	X	X	X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Corispermum hyssopifolium	Bugseed			X	
Cornus obliqua	Pale dogwood	X	X	X	
Cornus racemosa	Gray dogwood	X	X		
Cornus rugosa	Round-leaved dogwood		X		T
Cornus stolonifera	Red-osier dogwood	X	X	X	
Cornus stolonifera baileyi	Dunes dogwood			X	
Crepis capillaris	Hawk's bear			X	A
Cuscuta coryli	Hazel dodder			X	
Cuscuta gornovii	Common dodder			X	
Cycloloma atriplicifolium	Winged pigweed		X	X	
Cyperus erythrorhizos	Red-footed nut sedge			X	
Cyperus esculentus	Field nut sedge		X		
Cyperus ferruginescens	Rusty nut sedge	X	X	X	
Cyperus filiculmis	Slender sand cyperus		X		
Cyprerus rivularis	Brook nut sedge	X	X	X	
Cyperus schweinitzii	Rough sand cyperus	X		X	
Cyperus strigosus	Long-scaled nut sedge	X		X	
Cypripedium acaule	Stemless lady's slipper				W
Cypripedium calceolus parviflorum	Small yellow lady's slipper		X		R
Cypripedium calceolus pubescens	Large yellow lady's slipper		X		W
Daucus carota	Wild carrot	X	X	X	A
Descurainia sophia	Flixweed		X	X	A
Desmodium canadense	Showy tick trefoil	X	X	X	
Desmodium paniculatum	Panicled tick trefoil	X	X	X	
Desmodium sessilifolium	Sessile-leaved trefoil	X			
Dianthus armeria	Deptford pink			X	A
Diervilla lonicera	Dwarf honeysuckle			X	R
Digitaria ischaemum	Smooth crab grass			X	A
Digitaria sanguinalis	Ciliate crab grass			X	A
Diplotaxis muralis	Wall rocket		X	X	A
Diplotaxis tenuifolia	Sand rocket		X		A
Drosera intermedia	Narrow-leaved sundew			X	R
Dryopteris spinulosa	Spinulose shield fern			X	
Dryopteris thelypteris	Marsh shield fern	X	X	X	
Dulichium arundinaceum	Three-way sedge			X	
Echinochloa crusgalli pubescens	Barnyard grass		X	X	
Echinocystis lobata	Wild cucumber		X		
Echium vulgare	Viper's bugloss	X			A
Eleocharis acicularis	Needle spike rush			X	
Eleocharis compressa	Flat-stemmed spike rush			X	
Eleocharis elliptica	Golden-seeded spike rush	X	X	X	
Eleocharis engelmannii	Engleman's spike rush		X		
Eleocharis erythropoda	Red-footed spike rush	X	X	X	
Eleocharis geniculata	Knee spike rush		X	X	E
Eleocharis intermedia fernaldii	Matted spike rush			X	
Eleocharis smallii	Marsh spike rush			X	
Elodea canadensis	Common waterweed			X	
Elodea nuttallii	Slender waterweed			X	
Elymus canadensis	Canada rye	X	X	X	
Epilobium ciliatum	Northern willow herb			X	
Equisetum arvense	Horsetail	X	X	X	
Equisetum hymale	Tall scouring rush	X	X	X	
Equisetum variegatum	Small scouring rush			X	E
Equisetum × *ferrissii*				X	
Equisetum × *laevigatum*	Smooth scouring rush	X		X	
Equisetum × *trachyodon*			X		

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Eragrostis cilianensis	Stink grass			X	A
Eragrostis hypnoides	Creeping love grass				A
Eragrostis pectinacea	Small love grass	X		X	
Eragrostis poaeoides	Low love grass		X	X	A
Eragrostis spectabilis	Purple love grass	X		X	
Eragrostis trichodes	Tall love grass			X	A
Erechitites hieracifolia	Fireweed				
Erigeron annuus	Annual fleabane			X	
Erigeron canadensis	Horseweed	X	X	X	
Erigeron philadelphicus	Marsh fleabane			X	
Erigeron pulchellus	Robin's plaintain		X	X	
Erigeron strigosus	Daisy fleabane	X	X		
Eriophorum angustifolium	Narrow-leaved cotton grass		X	X	T
Eryngium yuccifolium	Rattlesnake master		X		
Eupatorium altissimum	Tall boneset	X	X	X	
Eupatorium maculatum	Spotted joe pye weed	X	X	X	
Eupatorium perfoliatum	Common boneset	X	X	X	
Eupatorium rugosum	White snakeroot		X		
Eupatorium serotinum	Late boneset	X	X	X	
Euphorbia corollata	Flowering spurge	X	X	X	
Euphobia dentata	Toothed spurge			X	A
Euphorbia maculata	Nodding spurge			X	A
Euphobia polygonifolia	Seaside spurge			X	
Euphobia supina	Spotted creeping spurge			X	A
Festuca elatior	Tall fescue		X		A
Fragaria virginiana	Wild strawberry	X	X	X	
Fraxinus americana	White ash			X	
Fraxinus pennsylvanica subintegerrima	Green ash		X		
Galium aparine	Annual bedstraw			X	
Galium concinnum	Shining bedstraw			X	
Galium obtusum	Wild madder	X	X		
Galium pilosum	Hairy bedstraw				
Galium tinctorium	Stiff bedstraw			X	
Gaylussacia baccata	Box huckleberry			X	
Gentiana andrewsii	Closed gentain			X	
Gentiana crinita	Fringed gentain		X	X	
Gentiana procera	Small fringed gentain		X	X	
Geranium carolinianum	Carolina cranesbill			X	
Geranium maculatum	Wild geranium			X	
Geum laciniatum trichocarpum	Rough avens		X		
Glechoma hederacea	Ground ivy			X	A
Gleditsia triacanthos	Honey locust	X		X	A
Glyceria borealis	Northern manna grass			X	E
Glyceria septentrionalis	Floating manna grass			X	
Glyceria striata	Fowl meadow grass	X	X	X	
Gnaphalium obtusifolium	Old-field balsam			X	
Habenaria ciliaris	Orange fringed orchid			X	
Habenaria clavellata	Club-spur orchid			X	
Habenaria flava herbiola	Tubercled orchid	X		X	
Habenaria hyperborea huronesis	Northern bog orchid			X	
Habenaria psycodes	Purple fringed orchid			X	
Hamamelis virginiana	Witch hazel			X	
Helianthemum canadense	Common rockrose			X	
Helianthus divaricatus	Woodland sunflower	X	X	X	
Helianthus grosseserratus	Sawtooth sunflower	X		X	
Helianthus occidentalis	Western sunflower	X		X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Helianthus petiolarus	Petioled sunflower			X	A
Helianthus rigidus	Prairie sunflower			X	
Heliopsis helianthoides	False sunflower		X		
Heteranthera dubia	Water star grass			X	
Hieracium caespitosum	Field hawkweed			X	A
Hieracium canadense fasciculatum	Canada hawkweed			X	
Hieracium gronovii	Hairy hawkweed			X	
Hieracium scabrum	Rough hawkweed			X	
Hordeum jubatum	Squirrel-tail grass			X	A
Hypericum canadense	Canadian St. John's wort			X	
Hypericum lamianum	Kalm's St. John's wort	X	X		
Hypericum majus	Sand St. John's wort			X	R
Hypericum virginicum fraseri	Marsh St. John's wort			X	
Hypoxis hirsuta	Yellow star grass	X			
Hystrix patula	Bottlebrush grass			X	
Ilex verticillata	Winterberry		X	X	
Impatiens capensis	Spotted touch-me-not	X	X	X	
Impatiens pallida	Pale touch-me-not	X	X	X	
Iris germanica	German iris			X	A
Iris pseudacorus	Tall yellow iris			X	A
Iris virginica shrevei	Blue flag	X	X	X	
Juncus balticus littoralis	Lake shore rush	X	X	X	W
Juncus brachycephalus	Short-headed rush		X	X	
Juncus canadensis	Canadian rush		X	X	
Juncus diffusissimus	Slimpod rush			X	
Juncus dudleyi	Dudley's rush	X	X	X	
Juncus effusus solutus	Common rush			X	
Juncus greenei	Greene's rush			X	
Juncus interia	Inland rush		X		
Juncus marginatus	Grass-leaved rush			X	
Juncus nodosus	Joint rush	X	X	X	
Juncus pelocarpus	Brown-fruited rush			X	T
Juncus scripoides	Round-headed rush			X	E
Juncus tenuis	Path rush	X	X	X	
Juncus torreyi	Torrey's rush	X	X	X	
Juniperus virginiana crebra	Eastern red cedar			X	
Koeleria cristata	June grass	X		X	
Krigia biflora	False dandelion	X		X	
Krigia virginica	Dwarf dandelion			X	
Kuhnia eupatroioides corymbulosa	False boneset			X	
Lactuca canadensis	Wild lettuce	X		X	
Lactuca serriola	Prickly lettuce	X			A
Lathyrus japonicus glaber	Beach pea			X	
Lathyrus orchroleucus	Pale vetchling			X	T
Lathyrus palustris myrtifolius	Marsh vetchling	X		X	
Lechea villosa	Hairy pinweed			X	
Leersia oryzoides	Rice cut grass		X	X	
Leersia virginica	White grass	X			
Lepidium virginicum	Common peppergrass			X	
Leptoloma cognatum	Fall witch grass			X	
Lespedeza capitata	Round-headed bush clover	X		X	
Lespedeza virginica	Slender bush clover			X	
Liatris aspera	Rough blazing star	X	X	X	
Liatris cyclindracea	Cylindrical blazing star	X	X	X	
Liatris spicata	Marsh blazing star	X	X	X	
Lilium philadelphicum andinum	Prairie lily	X	X	X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Linaria canadensis	Blue toadflax			X	
Linaria vulgaris	Butter-and-eggs			X	A
Linum medium texanum	Small yellow flax		X	X	
Liparis lilifolium	Purple twayblade	X		X	
Liparis loeselii	Green twayblade		X	X	R
Liriodendron tulipifera	Tulip tree		X		
Lithospermum canescens	Hoary puccoon	X	X	X	
Lithospermum croceum	Hairy puccoon	X	X	X	
Lobelia kalmii	Bog lobelia		X	X	
Lobelia siphilitica	Great blue lobelia	X		X	
Lobelia spicata	Pale spiked lobelia	X	X		
Lonicera dioica	Red honeysuckle		X	X	
Lonicera × muendenuensis	Common fly honeysuckle	X	X	X	A
Lonicera tatarica	Tartarian honeysuckle	X	X		A
Ludwigia alternifolia	Seedbox			X	
Ludwigia palustris ameriana	Marsh purslane			X	
Ludwigia polycarpa	False loosestrife			X	
Ludwigia sphaerocarpa deamii	Round-fruited loosestrife			X	E
Lupinus perennis occidentalis	Wild lupine	X		X	
Lychnis alba	White campion	X		X	A
Lycopus americanus	Common water horehound	X	X	X	E
Lycopus asper	Rough water horehound	X		X	A
Lycopus rubellus	Stalked water horehound			X	
Lycopus uniflorus	Northern bugle weed		X	X	
Lycopus virginicus	Bugle weed			X	
Lysimachia lanceolata	Lance-leaved loosestrife	X		X	
Lysimachia quadriflora	Four-leaved loosestrife	X	X		
Lysimachia terrestris	Swamp candles	X		X	
Lysmachia thysiflora	Tufted loosestrife			X	
Lythrum alatum	Winged loosestrife	X	X	X	
Lythrum salicaria	Purple loosestrife	X	X	X	A
Maianthemum canadense interius	Hairy Canada mayflower	X	X	X	
Malus ioensis	Iowa crabapple	X	X	X	
Medicago lupulina	Black medic	X		X	A
Melampyrum lineare latifolium	Cow wheat			X	
Melilotus alba	Sweet white clover	X	X	X	A
Melilotus officinalis	Sweet yellow clover			X	A
Mentha arvensis villosa	Wild mint			X	
Mimulus ringens	Monkey flower		X	X	
Mirabilis nyctaginea	Wild four o'clock			X	A
Mollugo verticillata	Carpet weed			X	A
Monarda fistulosa	Wild bergamot	X	X	X	
Monarda punctata villicaulis	Horse mint	X	X	X	
Monotropa uniflora	Indian pipe			X	
Morus alba	White mulberry		X	X	A
Muhlenbergia mexicana	Leafy stain grass			X	
Muhlenbergia racemosa	Upland wild timothy			X	A
Myosotis scorpioides	Common forget-me-not			X	A
Myriophyllum exalbescens	Spiked water milfoil			X	
Myriophyllum verticullatum pentinatum	Whorled water milfoil			X	T
Najas flexilis	Slender naiad			X	
Nepeta cataria	Catnip	X		X	A
Nuphar advena	Yellow pond lily			X	
Nymphaea tuberosa	White water lily		X	X	
Nyssa sylvatica	Sour gum			X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Oenothera biennis	Common evening primrose	X	X	X	
Oenothera rhombipetala	Western sand evening primrose		X	X	
Onoclea sensibilis	Sensitive fern	X		X	
Opuntia humifusa	Eastern prickly pear	X	X	X	
Orobanche uniflora	One-flowered broom rape			X	
Osmunda cinnamomea	Cinnamon fern			X	
Osmunda regalis spectabilis	Royal fern	X	X	X	
Oxalis europaea	Tall wood sorrel			X	
Oxypolis rigidior	Cowbane	X	X	X	
Panicum capillare	Old witch grass			X	
Panicum columnianum	Hemlock panic grass			X	E
Panicum depauperatum	Starved panic grass			X	
Panicum dichotomiflorum	Knee grass			X	E
Panicum flexile	Wiry panic grass		X	X	
Panicum implicatum	Old-field panic grass	X	X	X	
Panicum latiflorum	Broad-leaved panic grass			X	
Panicum lindheimeri	Smooth woolly panic grass			X	
Panicum oligosanthes scribnerianum	Scribner's panic grass		X	X	
Panicum perlongum	Long-stalked panic grass			X	
Panicum rigidulum	Munro grass			X	
Panicum villosissimum	White-haired panic grass		X	X	
Panicum villosissimum pseudopubescens	False white-haired panic grass			X	
Panicum virgatum	Switch grass	X	X	X	
Parnassia glauca	Grass of parnassus			X	
Parthenocissus inserta	Thicket creeper	X	X	X	
Parthenocissus quinquefolia	Virginia creeper	X	X	X	
Pedicularis canadensis	Wood betony	X	X	X	
Penthorum sedoides	Ditch stonecup			X	
Petalostemum purpureum	Purple prairie clover		X		
Phalaris arundinacea	Reed canary grass	X		X	A
Phleum pratense	Timothy			X	A
Phlox divaricata	Blue phlox		X		
Phlox glaberrima interior	Marsh phlox			X	
Phlox peniculata	Garden phlox			X	A
Phlox pilosa	Sand prairie phlox	X	X	X	
Phragmites australis	Common reed	X	X	X	A
Physalis heterophylla	Clammy ground cherry	X			
Physalis pubescens	Hairy ground cherry			X	A
Physalis subglabrata	Tall ground cherry			X	
Physalis virginiana	Lance-leaved ground cherry				
Physocarpus opulifolius	Ninebark		X	X	
Physostegia virginiana	False dragonhead	X	X		
Phytolacca americana	Pokeweed	X			
Pinus banksiana	Jack pine			X	R
Plantato major	Common plantain			X	A
Plantato rugelii	Red-stalked plantain	X		X	
Platanus occidentalis	Sycamore			X	
Poa annua	Annual blue grass			X	A
Poa compressa	Canada blue grass	X	X	X	A
Poa pratensis	Kentucky blue grass	X	X	X	A
Pogonia ophioglossoides	Snake-mouth orchid			X	R
Polanisia graveolens	Slammy weed			X	A
Polygala cruciata aquilonia	Cross milkwort			X	
Polygala polygama obtusata	Purple milkwort			X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Polygonatum canaliculatum	Smooth Solomon's seal	X	X	X	
Polygonella articulata	Jointweed			X	T
Polygonum amphibium stipulaceum	Water knotweed	X	X	X	
Polygonum aviculare	Common knotweed			X	A
Polygonum coccineum	Water heartease		X	X	
Polygonum convolvulus	Black bindweed			X	A
Polygonum hydropiperoides	Mild water pepper			X	E
Polygonum lapathifolium	Heartease			X	
Polygonum pensylvanicum	Pennsylvania knotweed			X	
Polygonum persicaria	Lady's thumb			X	A
Polygonum punctatum	Smartweed	X		X	
Polygonum scandens	Climbing false buckweat			X	
Polygonum tenue	Slender knotweed			X	
Pontederia cordata	Pickerel weed			X	
Populus deltoides	Eastern cottonwood	X	X	X	
Populus grandidentata	Large-toothed aspen		X		
Populus tremuloides	Quaking aspen	X	X	X	
Portulaca oleracea	Purslane		X		A
Potamogeton amplifolius	Large-leaved pondweed			X	
Potamogeton foliosus	Leafy pondweed			X	
Potamogeton gramineus	Grass-leaved pondweed			X	
Potamogeton illinoensis	Illinois pondweed			X	
Potamogeton natans	Common pondweed			X	
Potamogeton nodosus	Long-leaved pondweed			X	
Potamogeton pectinatus	Sago pondweed			X	
Potamogeton pulcher	Spotted pondweed			X	Ex
Potamogeton pusillus	Small pondweed			X	R
Potamogeton robbinsii	Fern pondweed			X	E
Potentilla fruticosa	Shrubby cinquefoil		X	X	
Potentilla palustris	Marsh cinquefoil		X	X	
Potentilla recta	Sulfur cinquefoil			X	A
Potentilla simplex	Common cinquefoil			X	
Prenanthes alba	White lettuce		X	X	
Prenanthes racemosa	Glaucous white lettuce		X	X	
Proserpinaca palustris crebra	Mermaid weed		X	X	
Prunella vulgaris lanceolata	Self heal		X	X	
Prunus pumila	Sand cherry		X	X	
Prunus serotina	Wild black cherry	X	X	X	
Prunus virginiana	Choke cherry	X	X	X	
Ptelea trifoliata	Hop tree			X	
Ptelea trifoliata millis	Downy hop tree			X	
Pteridium aquilinum latiuscuum	Bracken fern	X	X	X	
Pycnanthemum virginianum	Common mountain mint	X	X	X	
Quercus alba	White oak	X	X	X	
Quercus ellipsoidalis	Hill's oak	X			
Quercus velutina	Black oak	X	X	X	
Ranunculus flabellaris	Yellow water crowfoot			X	
Ranunculus sceleratus	Cursed buttercup			X	
Ratibida pinnata	Yellow coneflower	X			
Rhamnus cathartica	Common buckthorn	X	X		A
Rhamnus frangula	Glossy buckthorn	X	X	X	A
Rhus aromatica	Fragrant sumac	X	X	X	
Rhus aromatica arenaria	Dwarf fragrant sumac		X	X	
Rhus copallina latifolia	Winged sumac	X	X	X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Rhus glabra	Smooth sumac				
Rhus toxicodendron	Poison ivy	X	X	X	
Rhus typhina	Staghorn sumac	X	X	X	
Rhynchospora capiillacea	Hair beak rush		X	X	
Rhynchospora macrostachya	Horned beak rush		X	X	R
Ribes americanum	Wild black currant	X			
Robinea pseudoacacia	Black locust			X	A
Rorippa palustris hispida	Rough marsh cress			X	
Rosa blanda	Early wild rose			X	
Rosa multiflora	Multiflora rose	X		X	A
Rosa palustris	Swamp rose		X	X	
Rotala ramosior	Wheelwort			X	
Rubus flagellaris	Common dewberry	X		X	
Rubus hispidus	Swamp dewberry			X	
Rubus idaeus strigosus	Red raspberry		X	X	
Rubus occidentalis	Black raspberry			X	
Rudbeckia hirta	Black-eyed Susan	X	X	X	
Rumex acetosella	Field sorrel			X	A
Rumex altissimus	Pale dock			X	
Rumex crispus	Curley dock			X	
Satabia angularis	Rose gentain		X	X	A
Sagittaria graminea	Grass-leaved arrowhead			X	
Sagittaria latifolia	Common arrowhead			X	
Salix amygdaloides	Peach-leaved willow	X	X	X	
Salix discolor	Pussy willow	X		X	
Salix eriocephala	Heart-leaved willow			X	
Salix glaucophylloides	Blue-leaved willow	X	X	X	
Salix humilis	Prairie willow	X	X	X	
Salix interior	Sandbar willow		X	X	
Salix nigra	Black willow	X	X	X	
Salix pedicellaris hypoglauca	Bog willow			X	
Salix petiolaris	Meadow willow			X	
Salix purpurea	Purple willow		X		A
Salix syrticola	Dune willow			X	
Salsola kali tenuifolia	Russian thistle		X	X	A
Sambucus canadnesis	Elderberry	X	X	X	
Sanguinaria canadensis	Bloodroot			X	
Sanicula marilandica	Black snakeroot			X	
Saponaria officinalis	Bouncing bet	X		X	
Sassafras albidum	Sassafras	X	X	X	A
Satureja arkansana	Dogmint			X	E
Saxifraga pensylvanica	Swamp saxifrage		X		
Schizachyrium scoparium	Little bluestem	X	X	X	
Scirpus acutus	Hard-stemmed bulrush		X	X	
Scirpus atrovirens	Dark green rush		X	X	
Scirpus cyperinus	Wool grass			X	
Scirpus pendulus	Red bulrush		X		
Scirpus pungens	Chairmaker's rush	X	X	X	
Scirpus validus creber	Great bulrush	X	X	X	
Scleria pauciflora caroliniana	Few-flowered nut rush		X		E
Scleria triglomerata	Tall nut rush			X	
Scleria verticillata	Low nut rush		X	X	
Scutellaria epilobiifolia	Marsh skullcap	X		X	
Scutellaria lateriflora	Mad-dog skullcap	X	X	X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Senecio pauperculus	Balsam ragwort		X	X	
Setaria faberii	Giant foxtail			X	A
Setaria glauca	Yellow foxtail			X	A
Setaria viridis	Green foxtail			X	A
Silene antirrhina	Sleepy catchfly	X		X	
Silene cserei	Glaucous campion			X	A
Silene cucubalus	Bladder campion			X	A
Siphium integrifolium	Rosin weed	X			
Sisymbrium altissimum	Tumble mustard			X	A
Sisyrinchium albidum	Common blue-eyed grass	X	X	X	
Sium suave	Tall water parsnip		X	X	
Smilacina racemosa	Feathery false Solomon's seal	X		X	
Smilacina stellata	Stary false Solomon's seal	X	X	X	
Similax lasioneura	Common carrion flower	X		X	
Smililax rotundifolia	Green briar			X	
Smilax tamnoides hispida	Bristly green briar	X	X		
Solanum americanum	Black nightshade			X	A
Solanum ducamara	Bittersweet nightshade	X	X	X	A
Soliago altissima	Tall goldenrod		X	X	
Solidago caesia	Blue-stem goldenrod	X	X	X	
Solidago gigantea	Late goldenrod		X	X	
Solidago gramminifolia	Smooth grass-leaved goldenrod		X	X	
Solidago gramminifolia nutallii	Hairy grass-leaved goldenrod	X	X	X	
Solidago gymnospermoides	Vicid grass-leaved goldenrod		X	X	
Solidago juncea	Early goldenrod			X	
Solidago missouriensis fasciculata	Missouri goldenrod		X	X	
Solidago nemoralis	Old-field goldenrod	X	X	X	
Solidago ohioensis	Ohio goldenrod		X	X	
Solidago ptarmicoides	Prairie goldenrod			X	R
Solidago racemosa gillmanii	Dune goldenrod			X	
Solidago riddellii	Riddell's goldenrod		X		
Solidago ridida	Stiff goldenrod			X	
Solidago rugosa	Rough goldenrod		X	X	
Solidago sempervirens	Seaside goldenrod		X		A
Solidago speciosa	Showy goldenrod	X	X	X	
Solidago tenuifolia	Slender-leaved goldenrod			X	
Solidago uliginosa	Bog goldenrod		X		
Sonchus asper	Spiny sow thistle			X	A
Sonchus oleraceus	Store-front sow thistle			X	A
Sonchus uliginosus	Common sow thistle			X	A
Sorghastrum nutans	Indian grass		X	X	
Sparganium americanum	American bur reed	X		X	
Sparganium chlorocarpum	Dwarf bur weed			X	
Sparganium eurycarpum	Common bur reed			X	
Spartina pectinata	Prairie cord grass	X	X	X	
Sphenopholis intermedia	Slender wedge grass			X	
Spirea alba	Meadowsweet	X	X	X	
Spirea tomentosa rosea	Steeple bush		X	X	
Spiranthus ceruna	Nodding ladys' tresses		X	X	
Sporobolus asper	Rough dropseed			X	A
Sporobolus cryptandrus	Sand dropseed			X	
Stachys palustris homotricha	Woundwort			X	
Stachys tenuifolia hispida	Marsh hedge nettle			X	
Stipa spartea	Porcupine grass	X	X	X	

Appendix.—Continued.

Scientific name	Common name	DT	CP	MW	Status
Strophostyles helvula	Trailing wild bean			X	
Symphoricarpos orbiculatus	Coral berry			X	A
Talinum rugospermum	Fame flower			X	E
Taraxacum officinale	Common dandelion	X		X	A
Tephrosia virginiana	Goat's rue	X		X	
Teucrium canadense	Germander			X	
Thalictrum dioicum	Early meadow rue			X	
Tilia ameriana	Basswood			X	
Tofieldia glutinosa	False asphodel				R
Tradescantia ohiensis	Spider wort	X	X	X	
Tragopogon dubius	Sand goat's beard	X		X	A
Tragopogon pratensis	Common goat's bear			X	A
Trifolium hybridum	Alsike clover			X	A
Trifolium pratense	Red clover			X	A
Trifolium repens	White clover			X	A
Triglochin maritima	Common bog arrow grass		X	X	
Tripasis purpurea	Sand grass			X	
Triticum aestivum	Wheat			X	A
Typha angustifolia	Narrow-leaved cattail	X	X	X	A
Typha latifolia	Broad-leaved cattail	X	X	X	
Ulmus pumila	Siberian elm			X	A
Utricularia cornuta	Horned bladderwort			X	T
Utricularia gibba	Humped bladderwort			X	
Utricularia minor	Small bladderwort			X	
Utricularia vularis	Great bladderwort			X	
Vaccinium angustifolium	Early low blueberry			X	
Vaccinium pallidum	Late low blueberry			X	
Vallisneria americana	Eel grass			X	
Verbascum thapsus	Common mullein	X	X	X	
Verbana hastata	Blue vervain	X	X	X	A
Verbena stricta	Hoary vervain	X		X	
Veronia missurica	Missouri ironweed			X	
Veronicastrum virginicum	Culver's root		X		
Viburnum acerifolium	Maple-leaved arrow-wood			X	
Viburnum lentago	Nannyberry			X	
Viburnum prunifolium	Black haw	X			
Viburnum rafinesquianum	Downy arrow-wood			X	
Vicia americana	American vetch	X			
Viola conspersa	Dog violet		X		
Viola fimbriatula	Sand violet			X	
Viola lanceolata	Lance-leaved violet	X			
Viola pedata lineariloba	Bird's foot violet			X	
Viola pubescens	Yellow violet			X	
Viola sagittata	Arrow-leaved violet	X			
Viola sororia	Common blue violet		X		
Viola tricolor	Pansy violet			X	
Vitis aestivalis	Summer grape	X			A
Vitis labrusca	Fox grape	X			
Vitis riparia	Riverbank grape		X	X	
Vitis vulpina	Froot grape	X			
Xanthium strumarium	Cocklebur			X	A
Zizaia aquatica	Wild rice	X		X	
Zizia aurea	Golden Alexander	X		X	

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A view of railroad trestles and a toll road (I-90) crossing south of U.S. Steel property and within the U.S. Steel river reach. Transportation corridors crisscross the Calumet Region and the Grand Calumet River, with many roads and rails and an airport.

Much of the native vegetation along the Grand Calumet River has been replaced by nonnative invasive species. Cattails tend to dominate the bordering wetlands, but there are a few remaining high-quality areas that maintain native populations, including Clark and Pine East and the DuPont property.

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AQUATIC MACROINVERTEBRATES OF THE GRAND CALUMET RIVER

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ABSTRACT. The Grand Calumet River is potential habitat for a rich community of aquatic macroinvertebrates. Historical surveys of these organisms have been limited to post-industrialization of the Calumet Region; but because river habitats and conditions prior to industrialization have been described, past macroinvertebrate community composition can be inferred. In the past 20 years, several surveys have been conducted in the Grand Calumet that have focused on a limited area, but when these studies are amassed the information available covers much of the river. In this paper, the aquatic macroinvertebrate communities in the river are described, and options for restoration are discussed. Many of the macroinvertebrates present are indicators of high levels of pollution, but a few pollution-sensitive species have been found. There is evidence, however, that the sediment quality has improved since the 1960's, likely due to pollution controls that have been put into place. Restoration opportunities should consider the macroinvertebrate community and the potential to improve sediment habitat without damaging the community structure.

Keywords: Grand Calumet River, aquatic macroinvertebrates, pollution indicators

Macroinvertebrates—animals visible to the naked eye but that do not have backbones—are an extremely large, diverse group. Those with aquatic life stages are sensitive in varying degree to the physical and chemical characteristics of their aquatic environment, such as water temperature, flow rate, acidity, dissolved oxygen concentration, siltation rate, and types of pollution present. Aquatic macroinvertebrates can therefore be quite useful in indicating the status or quality of aquatic habitats. We describe the historical and present distribution of aquatic macroinvertebrates in the Grand Calumet River and Indiana Harbor Canal to ascertain present macroinvertebrate habitat quality and to explore sediment clean-up and restoration alternatives and their possible effects on macroinvertebrate communities.

HISTORICAL MACROINVERTEBRATE COMMUNITIES

The Grand Calumet River has undergone many changes in its history, as described in detail in other papers in this volume. The macroinvertebrate populations in the river have responded to these changes as various characteristics of their habitat were altered. Although there are no records for the macroinvertebrate communities prior to channelization and industrialization, enough is known about the characteristics of the river to estimate community composition. The Grand and Little Calumet Rivers once formed a slow-flowing, heavily-vegetated river that drained a vast wetland and emptied into Lake Michigan near present-day Marquette Park and the Grand Calumet Lagoons (Moore 1959). The rivers probably supported what Shelford (1977) calls a sluggish river community.

Shelford divided the sluggish river community into three "formations," the pelagic formation, the sand and silt bottom formation, and the zone of vegetation formation (1977). The pelagic, or open-water, formation is well-developed in larger rivers and was probably most important near the mouth of the Grand Calumet. This does not differ greatly from the pelagic formation of Lake Michigan, which includes copepods, cladocerans, roundworms, planarians, and leeches.

The sand and silt bottom formation includes mussels (*Anodonta grandis* and *Quadrula un-*

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dulata), snails (*Goniobasis livescens*), midge larvae, bryozoans (*Plumatella*), and occasional caddisfly larvae (*Hydropsyche*). Near the margin, a sandy bottom will include occasional snails (*Goniobasis*, *Pleurocera*, and *Campeloma*), midge larvae, occasional burrowing mayfly larvae, a number of mussels (*Unio gibbosus* and *Quadrula rubiginosa* being most characteristic), and occasionally a long-legged dragonfly larva (*Macromia taeniolata*). A silty bottom fauna includes the mussels *Quadrula undulata* and *Lampsilis siliquoidea*, the burrowing mayfly larva *Hexagenia*, midge larvae, segmented worms, sphaeriid clams, and the mud leech *Haemopis grandis*.

The zone of vegetation formation contains the water scorpion *Ranatra fusca*, the creeping water bug *Pelocoris femoratus*, the small water bug *Zaitha fluminea*, water boatman, the stillwater brook beetle *Elmis quadrinotatus*, several species of predaceous diving beetles, water scavenger beetles, mayfly larvae (*Caenis* and *Callibaetis*), the damselfly larva *Ischnura verticalis*, and dragonfly larvae (Aeschnidae and Libellulidae). It includes the pulmonate snails *Physa integra*, *Helisoma anceps*, and often species of *Lymnaea*. In addition, it includes the crayfish *Cambarus propinquus*, the amphipods *Hyalella azteca* and *Gammarus fasciatus*, viviparous snails (*Campeloma*), and an occasional mussel (*Anodonta grandis*). This zone is well-developed in the Grand Calumet River.

As the area became more populated and industrialized, the Grand Calumet River was degraded both physically and chemically. Canals and ditches were dug, wetlands were drained and filled, and stretches of river were dredged or moved, severely altering the hydrology of the area (Moore 1959). Industrial waste, sewage, and urban runoff increased the river's flow and contributed large amounts of solids, including organic matter and toxic chemicals. Between 1913–1937, many of the Chicago region's natural areas that Shelford studied were severely damaged, including a Grand Calumet site that was "destroyed by industrial waste" (Shelford 1977). Into the 1960's, most of the river was devoid of higher forms of aquatic life (FWPCA 1966). Since then, however, pollution controls have resulted in improvements in the river's water quality and aquatic communities. For example, while only 22–108 earthworms/m^2 were found in Indiana Harbor mouth sediments in the early 1960's, between 2400 and 500,000/m^2 were found in the same area in 1973 (CMSD 1980). Although aquatic earthworms are still the dominant taxon in the sediments of the Indiana Harbor and Canal, other less pollution-tolerant macroinvertebrates are now, at least, present (IDEM unpubl. data; Risatti & Ross 1989).

MACROINVERTEBRATE STUDIES

Information from five studies was combined to develop a fairly comprehensive database on Grand Calumet River macroinvertebrates. Following is a short description of the macroinvertebrate study methods in chronological order. See Fig. 1 for locations.

U.S. Geological Survey and Indiana Dunes National Lakeshore study.—Benthic (bottom) macroinvertebrate data from the Grand Calumet River Lagoons were collected by the U.S. Geological Survey from November 1978 to July 1980 and published by Hardy (1984). Organisms were collected on jumbo multi-plate artificial substrates placed in the East (NPS1) and West (NPS2) Lagoons for six weeks. One jumbo multi-plate substrate was placed in each of the two sites. The sites were sampled in November 1978, August 1979, and July 1980. All organisms were identified to genus, except the leeches (Hirudinea), earthworms (Oligochaeta), and water mites (Acari).

Indiana Department of Environmental Management study.—Benthic macroinvertebrate data from the Grand Calumet River and Indiana Harbor Canal were collected by the Indiana Department of Environmental Management from 1979–1988 (unpublished). The 1986–1988 data have been summarized by Bright (1988). Macroinvertebrates were collected with one to three multi-plate Hester-Dendy artificial substrate samplers per site. The samplers were generally left in the water from 6–8 weeks. Two samplers were collected from the East Branch of the Grand Calumet at Virginia Street (IDEM1) in 1987. Three samplers were collected from the East Branch at Bridge Street (IDEM2) in 1986, and two in both 1987 and 1988. Two samplers were collected from the East Branch at Cline Avenue (IDEM3) in both 1986 and 1988, and one in 1987. Three samplers were collected from the East Branch at Kennedy Avenue (IDEM4) in 1986 and two in 1988. Three samplers were collected from the West Branch of the Grand

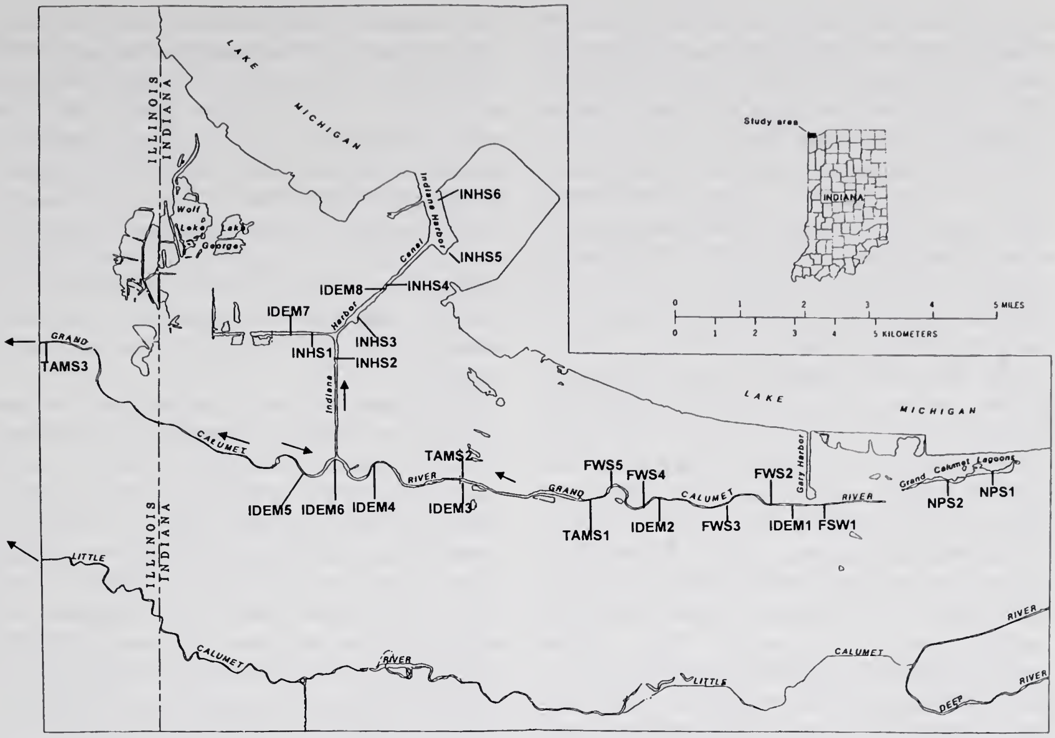

Figure 1.—Map of the study area with macroinvertebrate sampling sites identified. National Park Service sites from Hardy (1984); Indiana Department of Environmental Management sites from Bright (1988); Indiana Natural History Survey sites from Risatti & Ross (1989); TAMS sites from Mierzwa et al. (1991); and Fish amd Wildlife Service sites from Sobiech et al. (1994).

Calumet at Indianapolis Boulevard (IDEM5) in 1986. One sampler was collected from the mouth of the West Branch (IDEM6) in 1987 and two in 1988. Three samplers were collected from Lake George Canal at the railroad bridge (IDEM7) in 1986 and one in 1987. Three samplers were collected from Indiana Harbor Canal at Dickey Rd (IDEM8) in 1979, 1980, and 1981 and two in 1986, 1987, and 1988. Most organisms other than the aquatic earthworms were identified to genus (or species, if possible); however, the midges (Chironomidae) were usually not identified beyond family from every Hester-Dendy collected during a single sampling.

Illinois Natural History Survey study.—Benthic macroinvertebrate data from Indiana Harbor and Indiana Harbor Canal were collected by the Illinois Natural History Survey (INHS) on 3–4 May 1988 (Riatti & Ross 1989). Two petite Ponar grab samples were collected from each site, one for organism enumeration and identification, and one for determination of wet and dry biomass standing crop for the dominant taxa. Each grab sample was washed in a #30 mesh screen bucket and preserved in 10% buffered formalin. One site (INHS1) was located in Lake George Canal, just west of Indianapolis Boulevard. Three sites were located in Indiana Harbor Canal: INHS2, downstream of Columbus Drive; INHS3, downstream of Route 912; and INHS4, downstream of Dickey Road. Two sites were located in Indiana Harbor: INHS5, near the south end of the harbor; and INHS6, near the north end of the harbor. Sexually mature tubificid earthworms were identified to species level; other organisms were identified to family or genus level.

TAMS Consultants, Inc., study.—Benthic macroinvertebrate data from the Grand Calumet River were collected by TAMS Consultants, Inc. in 1990 and 1991 (Mierzwa et al. 1991). Three petite Ponar grab samples were collected from each site for each sampling period. Each sample was washed in a #30 mesh screen bucket and preserved in 10% buffered formalin. The East Branch was sampled at Route 12 (TAMS1) in July 1990, November 1990, and May 1991, and at Cline Avenue (TAMS2) in November 1990 and May 1991; the West Branch was sampled at Burnham Avenue (TAMS3) in November 1990, May 1991, and July 1991. Most organisms were identified to genus or species level, except the aquatic earthworms and midges, which were identified to family and subfamily. Numerical data were not published.

U.S. Fish and Wildlife Service study.—Benthic macroinvertebrate data from the East Branch of the Grand Calumet River were collected by the U.S. Fish and Wildlife Service in 1994 (Sobiech et al. 1994). Five multi-plate artificial substrate samplers consisting of five 5.8 cm diameter circular discs were placed at each site on 19 May 1994 and were retrieved on 29 June 1994. Qualitative (non-numerical) sampling was also performed. Only qualitative sampling was possible at the site upstream of Tennessee Street (FWS1). The East Branch was also sampled: FWS2, downstream of Broadway Avenue; FWS3, upstream of Interchange 13 entrance/exit ramps of I-90; FWS4, downstream of Bridge Street; and FWS5, at the Wabash railroad trestle. All organisms were identified to family, except the aquatic earthworms (Oligochaeta) and leeches (Hirudinea) to class and the scuds (Amphipoda), and crayfish (Decapoda) to order.

MACROINVERTEBRATES BY RIVER REACH

Lagoons reach.—This section includes the Grand Calumet River Lagoons east of USX (U.S. Steel Co.), and the sites NPS1 and NPS2 (Fig. 1). The Lagoons reach is different from the other reaches in that it is connected to the rest of the river by partially-constricted culverts. The most common taxa in this reach were the snail genus *Ferrissia* and the scud genus *Hyalella* in the East Lagoon and *Hyalella*, the midge genus *Glyptotendipes*, and the damselfly genus *Ischnura* in the West Lagoon (Hardy 1984) (Table 1). Although none of these taxa are considered particularly sensitive to pollution, the highest diversity of benthic invertebrates, including several sensitive taxa not found anywhere else, was found in this reach (Table 2).

Interestingly, the diversity indexes in the West Lagoon were lower than in the East Lagoon during wet periods—November 1978 and August 1979—and higher during the dry period—July 1980 (Hardy 1984). The suggested causes were lower seepage from the landfills north and south of the West Lagoon and greater organic enrichment in the East Lagoon. In addition, high ammonium concentrations in the West Lagoon (130–160× those common in surface water) corresponded with low diversity indexes, suggesting a possible source of stress on the West Lagoon community.

USX reach.—This reach includes the East Branch of the Grand Calumet River bordering the USX property. Sampling sites from east to west are: FWS1, IDEM1, FWS2, FWS3, IDEM2, FWS4, and FWS5 (Fig. 1). The most common taxa found in this reach were midges, the snail family Physidae, aquatic earthworms, and leeches (Table 1). In addition, the snail genus *Ferrissia* was common at IDEM2. At IDEM2, the only site at which midges were identified further than family level, the most common midge was *Cricotopus bicinctus*. Invertebrate Community Index (ICI) metric evaluation of the FWS study indicated that the invertebrate community of this reach was severely impaired (Sobiech et al. 1994). All sites received a total ICI score of 2 or lower and were classified as having very poor or poor invertebrate biotic integrity. The unbalanced trophic structure of the community, which was dominated by gathering collectors, also indicated degraded environmental conditions.

Gary Sanitary District reach.—This reach includes the East Branch of the Grand Calumet River from the USX property to Cline Avenue. Sampling sites from east to west include: TAMS1, TAMS2, and IDEM3 (Fig. 1). The most common taxa in this reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 (Table 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselflies and higher numbers of midges at IDEM3 is probably due to the use of Hester-Dendy artificial substrates at that site versus a petite Ponar at the TAMS sites. Mierzwa et al. (1991) found that, although the species richness, species diversity, and equitability of TAMS1 and TAMS2 were fair, the Macroinvertebrate Biotic Indices (MBIs) were quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

DuPont reach.—This section includes the East Branch of the Grand Calumet River from Cline Avenue to the Indiana Harbor Canal. Sampling sites from east to west include: TAMS2, IDEM3, and IDEM4 (Fig. 1). Note that TAMS2 and IDEM3 are also included in the Gary Sanitary District Reach and are listed under that reach in Fig. 1. The most common taxa found in the DuPont Reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 and IDEM4 (Table 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselflies and higher numbers of midges at the IDEM sites is probably due to the use of Hester-Dendy artificial substrates at those sites versus a petite Ponar at TAMS2. Mierzwa et al. (1991) found that, although the species richness, species diversity, and equitability of TAMS2 were fair, the Macroinvertebrate Biotic Index (MBI) was quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

Far West reach.—This reach includes the West Branch of the Grand Calumet River from the junction with the Little Calumet River (in Illinois) east to the Illinois/Indiana state line, and the site TAMS3 (Fig. 1). Only two taxa were identified at this site—the aquatic earthworm family Lumbriculidae and midge subfamily Chironominae (Table 1). Mierzwa et al. (1991) found this site to have very poor macroinvertebrate habitat, as indicated by its consistently low species richness, diversity, and equitability, and high (low quality) MBI.

Culverts reach.—This reach includes the West Branch of the Grand Calumet River from the Illinois/Indiana state line east to Columbia Avenue. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Hammond Sanitary District reach.—This reach includes the West Branch of the Grand Calumet River from Columbia Avenue in the west to the Hammond/East Chicago boundary. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Roxanna Marsh reach.—This section includes the West Branch of the Grand Calumet River from the Hammond/East Chicago boundary east to Indianapolis Boulevard, and sampling site IDEM5 (Fig. 1). The most common taxa found were the snail genus *Physa*, the midge *Parachironomus abortivus*, and the midge *Chironomus decorus* (Table 1). All of these are quite pollution-tolerant (Table 2), suggesting very poor habitat. There is a hydrologic divide at the western end of this reach, so some of the water flows west to join the Little Calumet River and some flows east to Lake Michigan via the Indiana Harbor Canal.

East Chicago Sanitary District reach.—This section includes the West Branch of the Grand Calumet River from Indianapolis Boulevard to the Indiana Harbor Canal, and sampling site IDEM6 (Fig. 1). The most common taxa found were the aquatic earthworms and crane flies (Tipulidae) (Table 1). Since crane fly larvae are considered only slightly pollution-tolerant (Table 2), this site may have somewhat better macroinvertebrate habitat than most. However, although crane fly larvae were the majority of the organisms collected in 1987, earthworms were quite dominant in 1988 (IDEM unpubl. data), suggesting very poor habitat.

Canal reach.—This section is the portion of the Indiana Harbor Canal from the Grand Calumet River north to Columbus Drive. None of the sampling sites are found within this reach. However, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh, East Chicago Sanitary District, and DuPont reaches, which precede it in water flow.

Lake George reach.—This section is the western portion of Lake George Canal, ending approximately 330 m west of Indianapolis Boulevard, and it includes the site IDEM7 (Fig. 1). The most common taxa found were bryozoans (Bryozoa), aquatic earthworms, the snail genus *Physa*, and *Hydra* (Table 1). Most of these are highly pollution-tolerant (Table

Table 1.—Macroinvertebrate taxa identified from the various river sections (reaches). Indiana Dunes National Lakeshore sites (NPS) are from Hardy (1984); Indiana Department of Environmental Management sites (IDEM) are from Bright (1988); Illinois Natural History Survey sites (INHS) are from Risatti & Ross (1989); TAMS Consultants, Inc. sites (TAMS) are from Mierzwa et al. (1991); and U.S. Fish and Wildlife Service sites (FWS) are from Sobiech et al. (1994). X = present, C = 20% or more of the total individuals found in any sample. * This beetle, recorded as "*Gyraulus,*" is assumed to have been *Gyrinus.*

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Phylum Porifera													
Phylum Cnidaria													
Hydridae													
Hydra													
Phylum Platyhelminthes													
Turbellaria				X									
Phylum Nematoda											X		
Phylum Bryozoa													
Plumatella													
unidentified bryozoans													
Phylum Annelida													
Oligochaeta													
Lumbricidae										X	X		
Lumbriculidae										X	X		
Tubificidae													
Limnodrilus													
Limnodrilus cervix													
Limnodrilus hoffmeisteri													
Potamothrix vejdovskyi													
Quistadrilus multisetosus													
immature w/o capil. chaetae													
immature w/ capil. chaetae													
unidentified earthworms	X		X	C	X	X	C	C	X			C	C
Hirudinea													
Erpodellidae													
Dina microstoma?												*X*	
Dina parva										*X*			
Erpobdella punctata												*X*	*X*
Mooreobdella										*X*	*X*		
Mooreobdella fervida													*X*

Table 1.—Extended.

	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
Taxa	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Phylum Porifera								C			
Phylum Cnidaria											
Hydridae										C	X
Hydra				C							
Phylum Platyhelminthes											
Turbellaria			X								
Phylum Nematoda											
Phylum Bryozoa											
Plumatella								C			
unidentified bryozoans				C				C			
Phylum Annelida											
Oligochaeta											
Lumbricidae											
Lumbriculidae	X										
Tubificidae											
Limnodrilus					X	X					X
Limnodrilus cervix					X	X			X		
Limnodrilus hoffmeisteri					C	C	C		C	C	C
Potamothrix vejdovskyi						X					
Quistadrilus multisetosus						X	C		X		
immature w/o capil. chaetae					C	C	C		X	C	X
immature w/ capil. chaetae						X					
unidentified earthworms		X	C	C				C			
Hirudinea											
Erpodellidae						X					
Dina microstoma?											
Dina parva											
Erpobdella punctata											
Mooreobdella											
Mooreobdella fervida											

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Mooreobdella microstoma												X	X
Glossiphoniidae													
Helobdella											X		
Helobdella stagnalis							X					X	X
Placobdella										X	X		
unidentified leeches	X	X		X	X	C	X	C	X			C	C
leech cocoons													X
Phylum Mollusca													
Gastropoda													
Ancylidae													
Ferrissia	C						C						
Hydrobiidae											X		
Amnicola	X												
Lymnaeidae			X					X	X				
Lymnaea										X			
Physidae			C		C	X		C	X				
Aplexa										X			
Physa	X	X		X			C					C	X
Physella										X	X		
Planorbidae					X			X	X				
Gyraulus	X									X	X		
Helisoma												X	X
Planorbula	X												
Promenetus	X												
Promenetus?													
Valvatidae													
Valvata	X												
unidentified snails													
Pelecypoda													
Corbiculidae					X			X	X				

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Mooreobdella microstoma		X									
Glossiphoniidae											
Helobdella											
Helobdella stagnalis		X		X				X			
Placobdella											
unidentified leeches			X	X				X			
leach cocoons		X		X							
Phylum Mollusca											
Gastropoda											
Ancylidae											
Ferrissia							X				
Hydrobiidae									C		
Amnicola											
Lymnaeidae											
Lymnaea											
Physidae											
Aplexa		C	X	C				X			
Physa											
Physella								X			
Planorbidae											
Gyraulus											
Helisoma				X				X			
Planorbula											
Promenetus											
Promenetus?								X			
Valvatidae											
Valvata											
unidentified snails								X			
Pelecypoda											
Corbiculidae											

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Dreissenidae					X								
Sphaeriidae (unident.)												X	
Pisidium											X		
Sphaerium										X	X		
Phylum Arthropoda													
Branchiopoda													
"Cladocera"													
Amphipoda													
Hyalella	C	C		X									
unident. scuds									X				
Isopoda													
Caecidotea/Asellus	X	X											
Lirceus	X												
Decapoda													
Cambaridae						X							
Orconectes	X												
Arachnida													
Acari		X											
Insecta													
Ephemeroptera													
Baetidae													
Baetis		X											
Caenidae													
Caenis	X	X											
Heptageniidae													
Stenonema (*pulchellum* group)													
Odonata (Anisoptera)													
Aeshnidae			X			X		X	X				
Corduliidae													

Table 1.—Continued Extended.

Taxa	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Dreissenidae											
Sphaeriidae (unident.)				X	X						X
Pisidium					X						
Sphaerium									X		
Phylum Arthropoda											
Branchiopoda											
"Cladocera"				X							
Amphipoda											
Hyalella											
unident. scuds											
Isopoda											
Caecidotea/Asellus											
Lirceus											
Decapoda											
Cambaridae											
Orconectes											
Arachnida											
Acari											
Insecta											
Ephemeroptera											
Baetidae											
Baetis								X			
Caenidae											
Caenis											
Heptageniidae											
Stenonema (*pulchellum* group)								X			
Odonata (Anisoptera)											
Aeshnidae											
Corduliidae											

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Neurocordulia		X											
Tetragoneuria	X												
Libellulidae													
Erythemis													
Odonata (Zygoptera)													
Coenagrionidae						X		X	X				
Argia				X								X	X
Chromagrion	X	X											
Ischnura	X	C		X			X					X	
Lestidae									X				
unident. dameselflies							X					X	X
Trichoptera													
Hydropsychidae													
Cheumatopsyche													
Hydropsyche											X		
Hydropsyche orris?													
Hydropsyche simulans													
Hydropsyche simulans?													
Hydropsyche simulans pupae												X	
Hydroptilidae													
Neotrichia	X												
Orthotrichia	X												
Leptoceridae													
Anthripsodes		X											
Leptocerus		X											
Nectopsyche		X											
Oecetis		X											
Polycentropodidae													

Table 1.—Continued Extended.

	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
Taxa	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Neurocordulia											
Tetragoneuria											
Libellulidae											
Erythemis				X							
Odonata (Zygoptera)											
Coenagrionidae											
Argia		X		X							
Chromagrion											
Ischnura		X		X				X			
Lestidae											
unident. dameselflies		X	X								
Trichoptera											
Hydropsychidae								X			
Cheumatopsyche			X					X			
Hydropsyche											
Hydropsyche orris?								X			
Hydropsyche simulans								X			
Hydropsyche simulans?								X			
Hydropsyche simulans pupae											
Hydroptilidae											
Neotrichia											
Orthotrichia											
Leptoceridae											
Anthripsodes											
Leptocerus											
Nectopsyche											
Oecetis											
Polycentropodidae											

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Cyrnellus fraternus												X	
Neureclipsis													
Hemiptera													
Belostomatidae													
Lethocerus		X											
Corixidae									X				
Sigara	X												
Pleidae													
Plea		X											
Coleoptera													
Dysticidae													
Dytiscus				X									
Laccophilus		X											
Gyrinidae													
Dineutus		X											
Gyrinus?*													
Haliplidae													
Haliplus		X											
Diptera													
Ceratopogonidae													
Palpomyia	X	X											
unident. biting midges									X				
Chaoboridae													
Chaoborus							X						
Chironomidae													
Chironominae										X			
(Chironomini)													
Chironomus	X	X										X	X
Chironomus decorus													
Dicrotendipes/Limnochironomus	X	X											X

Table 1.—Continued Extended.

	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
Taxa	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Cyrnellus fraternus				X							
Neureclipsis			X								
Hemiptera											
Belostomatidae											
Lethocerus											
Corixidae											
Sigara											
Pleidae											
Plea											
Coleoptera											
Dysticidae											
Dytiscus											
Laccophilus											
Gyrinidae											
Dineutus											
*Gyrinus?**			X								
Haliplidae											
Haliplus											
Diptera											
Ceratopogonidae											
Palpomyia											
unident. biting midges			X								
Chaoboridae											
Chaoborus					X						
Chironomidae											
Chironominae	X										
(Chironomini)											
Chironomus			X								
Chironomus decorus		C									
Dicrotendipes/Limnochironomus								X			

Table 1.—Continued.

	Lagoons		USX Reach							Gary San. District			DuPont
Taxa	NPS1	NPS2	FWS1	IDEM1	FWS2	FWS3	IDEM2	FWS4	FWS5	TAMS1	TAMS2	IDEM3	IDEM4
Dicrotendipes nervosus													
Glyptotendipes	X	C										X	
Microtendipes	X												
Parachironomus													
Parachironomus abortivus												X	X
Phaenopsectra	X	X											
Polypedilum		X											
Polypedilum convictum							X					X	
Stenochironomus							X						
(Tanytarsini)													
Cladotanytarsus	X												
Rheotanytarsus													X
(Orthocladiinae)													
Cricotopus		X										C	X
Cricotopus bicinctus							C					C	X
Cricotopus intersectus												X	
Cricotopus sylvestris												X	X
Eukiefferiella		X											
Eukiefferiella discoloripes							X						
(Tanypodinae)													
Ablabesmyia		X											
Labrundinia		X											
Procladius sublettei													
Thienemannimyia group							X						
unident. midge larvae			X	X	C	C	C	X	C			X	C
unident. midge pupae							X					X	
Culicidae													
Tipulidae													
Empididae									X				
Stratiomyidae								X					
Syrphidae								X					

Table 1.—Continued Extended.

	Far West	Rox-anna	E. Chic.	L. George	Federal Dredging Project Reach						
Taxa	TAMS3	IDEM5	IDEM6	IDEM7	INHS1	INHS2	INHS3	IDEM8	INHS4	INHS5	INHS6
Dicrotendipes nervosus		X		X							
Glyptotendipes											
Microtendipes											
Parachironomus				X							
Parachironomus abortivus		C		X				X			
Phaenopsectra											
Polypedilum											
Polypedilum convictum											
Stenochironomus											
(Tanytarsini)											
Cladotanytarsus											
Rheotanytarsus				X				X			
(Orthocladiinae)											
Cricotopus				X							
Cricotopus bicinctus								X			
Cricotopus intersectus											
Cricotopus sylvestris								X			
Eukiefferiella											
Eukiefferiella discoloripes											
(Tanypodinae)											
Ablabesmyia											
Labrundinia											
Procladius sublettei		X									
Thienemannimyia group											
unident. midge larvae		C	X	X				X			
unident. midge pupae		X									
Culicidae			X								
Tipulidae			C								
Empididae											
Stratiomyidae											
Syrphidae											

2), indicating that the macroinvertebrate habitat is probably poor.

Federal Dredging Project reach.—The Federal Dredging Project reach, although not specifically addressed in this study, can provide additional information on Grand Calumet macroinvertebrate populations. This section includes the Indiana Harbor and Canal from Columbus Drive north to Lake Michigan and the eastern portion of Lake George Canal to approximately 330 m west of Indianapolis Boulevard. Sampling sites are: INHS1 in Lake George Canal; INHS2, INHS3, IDEM8, and INHS4 in Indiana Harbor Canal; and INHS5 nd INHS6 in Indiana Harbor (Fig. 1). The most common taxa found were aquatic earthworms, identified as the Family Tubificidae in the INHS sites, the snail family Hydrobiidae and hydras (Hydridae) at INHS5, and bryozoans (Bryozoa) at IDEM8 (Table 1).

Many taxa, such as the midges, mayflies (Ephemeroptera), caddisflies (Trichoptera), damselflies, and snails (other than Hydrobiidae), were identified at IDEM8 but not at the INHS sites. These differences likely stem from the different sampling methods used (Hester-Dendy *vs.* petite Ponar) and number of samples collected, rather than real differences in the communities. For example, both IDEM8 and INHS4 are in Indiana Harbor Canal near Dickey Road, yet at least 19 taxa were found at IDEM8 and only four at INHS4. The enumeration and identification data in the INHS study, however, were obtained from a single petite Ponar grab, whereas the IDEM data at this site are drawn from 15 Hester-Dendy artificial substrate collections over nine years. The IDEM data also show a general increase in richness and diversity from 1979–1988, with a peak in 1986 probably caused by historic highs in Lake Michigan water levels (Bright 1988). Although the invertebrate community in this reach is probably degraded, as indicated by the dominance of aquatic earthworms at every site, it may not be as poor as the INHS data suggest.

SPECIES LIST AND DESCRIPTIONS

Phylum Porifera
(Sponges)

Members of the Phylum Porifera, the sponges, are the simplest animals. Of the more than 5000 species of sponges, the vast majority are marine, and only about 27 species occur in the fresh waters of the United States and Canada (Frost 1991). Freshwater sponges are common in unpolluted ponds, lakes, streams, and rivers, and they may be found attached to almost any stable submerged object (Pennak 1989). Sponges were found in Indiana Harbor Canal (Federal Dredging Project Reach) at IDEM8 in 1986 (Fig. 1 and Table 1). They were described as "abundant" on one of the two Hester-Dendy samplers retrieved from that location and were not identified any further. Sponges are generally sensitive to variations in environmental conditions, and several U.S. species have become extinct within the last 20–40 years, mainly due to pollution (Pennak 1989). However, sponges have been observed in a variety of polluted waters, their distribution depending upon the type and quantity of pollutant and individual species tolerances (Harrison 1974).

Phylum Cnidaria
(Hydra)

Hydra spp. were found in 1987 and 1988 at three sites in the Federal Dredging Project reach—IDEM7, INHS5, and INHS6 (Fig. 1 and Table 1). They were identified as *Hydra* at IDEM7 and Hydridae at the other two sites. The class Hydrozoa has been rated quite tolerant of certain natural phenomena, such as high alkalinity, sulfate concentrations, sedimentation, and low stream gradients (USDA Forest Service 1989) (Table 2). Although hydras have been used as an indicator of moderately organically enriched streams and rivers in South Africa (Chutter 1972) (Table 2), a more recent study has found them to be characteristic of natural conditions (Patrick & Palavage 1994) (Table 2). Hydras are very sensitive to heavy metals and detergents (Slobodkin & Bossert 1991). It is likely that hydras inhabit other areas of the Grand Calumet River as well, since they are often either not collected or not well-preserved in routine collections due to their small size, soft bodies, and typically sessile habits.

Phylum Platyhelminthes
Class Turbellaria
(Flatworms)

Flatworms are common inhabitants of fresh waters, and more than 200 species occur in the fresh waters of North America (Kolasa 1991). Flatworms were identified at IDEM1 in the USX reach and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). They were not identified to a lower level than class due to the inherent difficulty of recognizing the very small microturbellarians, but most likely they were planarians. Flatworms have been rated quite tolerant of certain natural phenomena and moderately tolerant of general pollution (USDA Forest Service 1989; Illinois EPA 1985) (Table 2). Planarians are generally intolerant of organic pollution, although some species have been observed in heavily polluted waters (Kenk 1974). They have been used as indicators of slightly enriched waters (Chutter 1972) (Table 2). Planarians are generally less sensitive to pesticides and herbicides than other invertebrates (Kenk 1974). It is likely that there are also flatworms in some of the other study sites that were not observed because of their small size (Kolasa 1991).

Phylum Nematoda
(Roundworms)

Roundworms were found in the Gary Sanitary District and DuPont Reaches at TAMS2 (Fig. 1 and Table 1). They were not identified any further. Freshwater roundworms have been rated quite tolerant of certain natural phenomena and indicative of organically enriched or polluted waters (Table 2). However, they are not uniformly sensitive to pollutants (Poinar 1991), and a recent study did not rate them as being either pollution-tolerant or intolerant (Table 2). It is likely that roundworms also inhabit other areas, but their small size (most <1 cm in length) would make it easy for them to pass through the #30 sieves or to be unobserved during the separation of the macroinvertebrates from the rest of the samples.

Phylum Bryozoa/Ectoprocta & Endoprocta
(Moss animals)

Bryozoans have been called "moss animals" because colonies of some common species can resemble a mat of moss. Approximately 4000 marine species of bryozoans have been described, and there are only about 50 freshwater species, including about 22 in the United States (Pennak 1989). Freshwater bryozoans attach to submerged surfaces, and will grow on aquatic vegetation and almost any solid, biologically-inactive material (Wood 1991). They survive in both still and running water, but are generally restricted to relatively warm water.

Bryozoans were identified in the Lake George reach at IDEM7 and the Federal Dredging Project reach at IDEM8 in 1986, 1987, and 1988 and were described as "abundant" or "dominant" in most samples (Fig. 1 and Table 1). Those collected from IDEM8 in 1986 on one of the Hester-Dendy samplers were identified as *Plumatella*. Freshwater bryozoans have various pollution tolerances, with *Fredericella sultana*, *Plumatella emarginata*, and *P. repens* being particularly tolerant of contamination from sewage and industrial wastes (Bushnell 1974). All species have been found most often in clean or mildly polluted habitats, however, so none should be considered indicators of pollution.

Phylum Annelida
(Segmented worms)

The segmented worms include five classes that are represented in fresh waters. Of these, two—Oligochaeta and Hirudinea—were collected in the Grand Calumet River.

Class Oligochaeta (Aquatic earthworms).—Aquatic earthworms are smaller than their amphibious and terrestrial relatives, usually between 1–30 mm in length. The burrowing activity of aquatic earthworms can contribute greatly to sediment mixing and solute transport across the mud-water interface (Brinkhurst & Gelder 1991).

Aquatic earthworms were found at every site except NPS2 in the Lagoons reach (Fig. 1 and Table 1). They were identified simply as aquatic earthworms at the NPS, FWS, and IDEM sites. The Family Lumbricidae was collected at TAMS1 and 2 (Gary Sanitary District reach), and the Family Lumbriculidae was collected at TAMS1, 2, and 3 (Far West reach). The Family Tubificidae was identified at the INHS sites in the Federal Dredging Project reach as: *Limnodrilus*, *Limnodrilus cervix*, *Limnodrilus hoffmeisteri*, *Potamothrix vejdovskyi*, and *Quistadrilus multisetosus*. In addition, immature worms without capilliform chaetae were found at all six sites, and those with capilliform chaetae were found at INHS2.

Aquatic earthworms are generally considered quite tolerant of pollution and/or enrichment (Table 2). Species composition can be a valuable indicator, however, with a series of species groups inhabiting progressively more polluted stretches of rivers or more eutrophic lakes (Brinkhurst & Gelder 1991). In the Great Lakes, there are some species associations of Tubificidae characteristic of organically polluted bays and harbors: *Tubifex tubifex*, *Peloscolex multisetosus*, and several *Limnodrilus* species (dominated by *L. hoffmeisteri* and *T. tubifex*); *Aulodrilus*, *Potamothrix*, *Limnodrilus* and *Peloscolex ferox* are characteristic of eutrophic conditions; and *L. hoffmeisteri*, *T. tubifex*, and other species are characteristic of "clean" waters (Brinkhurst & Cook 1974).

Class Hirudinea (Leeches).—The leeches are predominantly freshwater organisms, with about 60 freshwater species known in the United States (Pennak 1989). They commonly inhabit ponds, marshes, lakes, and slow streams, particularly in the northern half of the country, and the same species may occur in a variety of environments. Leeches are represented in North America by four families, two of which were found in the Grand Calumet River: Erpobdellidae, which primarily prey upon macroinvertebrates and zooplankton; and Glossiphoniidae, which either prey upon macroinvertebrates or temporarily parasitize fish, turtles, amphibians, or water birds (Davies 1991).

Leeches were identified at all sites except FWS1 in the USX reach; TAMS3 in the Far West reach; and INHS1, 3, 4, 5, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). No leeches were identified below class at the NPS or FWS sites. Those in the Family Erpobdellidae were identified as *Dina microstoma* (uncertain), *Dina parva*, *Erpobdella punctata*, *Mooreobdella*, *Mooreobdella fervida*, and *Mooreobdella microstoma*. The Family Glossiphoniidae was represented by *Helobdella*, *Helobdella stagnalis*, and *Placobdella*. Cocoons were identified at IDEM4, 5, and 7. It is possible that the lack of leeches found at the INHS sites was partially due to the limited sampling done (i.e., one petite Ponar grab per site).

Leeches are generally considered pollution tolerant (Table 2); however, different leech species have different tolerances to pollution, with only about a dozen in the United States and Canada commonly or occasionally associated with polluted water (Sawyer 1974). *Helobdella stagnalis* and *Erpobdella punctata* are by far the most important of these, but they are common and can only be considered indicator species in terms of unusually high densities. *Mooreobdella microstoma* and *Dina parva* are occasionally associated with disturbed environments. Patrick & Palavage (1994) rated *Dina parva*, *Erpobdella punctata*, and *Helobdella stagnalis* as pollution-tolerant species (Table 2).

Phylum Mollusca
(Mollusks)

Class Gastropoda (Snails).—Snails were found at every site except TAMS3 in the Far West reach and INHS1, 2, 3, 4, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Family Ancylidae was identified to *Ferrissia*. The Family Hydrobiidae was identified to *Amnicola*. The Family Lymnaeidae was identified to *Lymnaea*. The Family Physidae was identified to *Aplexa*, *Physa*, and *Physella*. The Family Planorbidae was identified to *Gyraulus*, *Helisoma*, *Planorbula*, and *Promenetus*. The Family Valvatidae was identified to *Valvata*.

Most snails require high dissolved oxygen concentrations, so they are seldom found in severely polluted rivers or the deeper parts of lakes that become oxygen deficient (Pennak 1989). Other factors that can reduce the diversity of snails in a body of water are low pH values, heavy metals, pesticides, extreme temperatures, and organic pollution (Harman 1974). The pulmonates (Ancylidae, Lymnaeidae, Physidae, and Planorbidae) are more resistant to organic pollution. Of the snails found in these studies, *Valvata* and *Amnicola* are the least pollution tolerant (Table 2).

Class Pelecypoda (Bivalves).—Bivalves, including clams and mussels, live in almost all types of freshwater habitats but are particularly common in larger rivers (Pennak 1989). There are 266 species in North American fresh waters, including 227 in the Superfamily Unionacea, 37 in the Family Sphaeriidae (four introduced), and two additional exotics, *Corbicula fluminea* (Asiatic clam) and *Dreissena polymorpha* (zebra mussel) (McMahon 1991). The vast majority of freshwater bivalves feed by filtering suspended microscopic particles, such as organic detritus and plankton (Pennak

1989). Freshwater bivalves are hosts for various parasites, including flukes, roundworms, aquatic earthworm *Chaetogaster limnaei*, and water mites of the Family Unionicolidae.

Bivalves were identified at FWS2, 4, and 5 in the USX reach; TAMS1, TAMS2, and IDEM3 in the Gary Sanitary District and DuPont reaches; IDEM7 in the Lake George reach; and INHS1, 4, and 6 in the Federal Dredging Project reach (Fig. 1 and Table 1). Asiatic clams (Corbiculidae) were identified at FWS2, 4, and 5. Zebra mussels (Dreissenidae) were identified at FWS2. Sphaeriidae was identified to family at IDEM3, IDEM7, INHS1, and INHS6; *Pisidium* at TAMS2 and INHS1; and *Sphaerium* at TAMS1, TAMS2, and INHS4. No unionaceans were found.

Bivalves are adversely affected by various forms of pollution, including chemical wastes, asbestos, heavy metals, chlorine and paper mill effluents, urban wastewater effluents, and silt and acid discharges from mines (McMahon 1991). They have been rated both quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Table 2). Species diversity and density of unionaceans have declined greatly in North America in the last century, and many unionaceans are currently endangered (McMahon 1991). Many reasons have been postulated for this massive decline, including the freshwater pearling industry, extensive artificial impoundments, and channelization of drainage systems. *Corbicula* has been rated slightly tolerant of polluted conditions (Table 2). *Pisidium* and *Sphaerium* have been rated tolerant and somewhat tolerant of pollution (Table 2). Certain Sphaeriidae species, such as *Sphaerium transversum*, are tolerant of polluted, nearly septic conditions (Fuller 1974).

Phylum Arthropoda
(Subphylum Crustacea)

Although only about 10% of the nearly 40,000 species of crustaceans occur in fresh waters, they are extremely important in many freshwater ecosystem processes (Covich & Thorp 1991).

Class Branchiopoda
(Water fleas)

Water fleas, small (most < 1 mm in length) transparent animals, are widespread, living in all but the harshest freshwater habitats. Some water fleas are bottom dwellers (benthos), whereas others inhabit open water. Most water fleas are filter-feeders, eating a variety of small particles including bacteria, algae, ciliates, and small rotifers (Dodson & Frey 1991). They are an important food source for fish; in addition, they are eaten by hydras and immature and mature insects (Pennak 1989).

Water fleas were found at only one site—IDEM7 in the Lake George reach (Fig. 1 and Table 1). Two organisms were identified in 1986, and they were not identified to a lower taxonomic level. Water fleas have been rated quite tolerant of certain natural phenomena (Table 2). Pollution tolerances vary among species, but most (19 out of 22) of the water flea species identified in the Delaware and Neches Estuaries and the Flint River in New England were rated characteristic of natural conditions by Patrick & Palavage (1994).

Class Malacostraca

The class Malacostraca includes the superorders Pancarida (order Thermosbaenacea), Peracarida (orders Mysidacea, Amphipoda, and Isopoda), and Eucarida (order Decapoda) (Covich & Thorp 1991). Of these, amphipods (scuds), isopods (sow bugs), and decapods (crayfish and shrimp) were found in the Grand Calumet River.

Order Amphipoda (Scuds).—Scuds are found in unpolluted lakes, ponds, streams, brooks, springs, and subterranean waters (Pennak 1989). They are usually bottom species found only in shallow waters. Scuds are omnivorous, general scavengers, or detritus feeders and occasionally, filter feeders. Predators of scuds include fish, birds, aquatic insects, and amphibians, and parasites include tapeworms, flukes, roundworms, and Acanthocephala. In addition, algae and protozoans thrive on their external surfaces.

Scuds were found in both of the Grand Calumet Lagoons and in the USX reach (Fig. 1 and Table 1). They were identified simply as Amphipoda at FWS5, and to *Hyallela* (most likely *Hyallela azteca*) at NPS1, NPS2, and IDEM1. They were common at NPS1 and NPS2. Since scuds generally require high dissolved oxygen concentrations, they are usually limited to clean, cold waters (Covich & Thorp 1991). Also, they are especially sensitive to copper and a number of other heavy metals. Scuds (and *Hyallela azteca*) have been rated quite tolerant of certain natural phenomena (Table 2). *Hyallela azteca* has been rated pollution-tolerant, moderately tolerant, and indicative of very significant organic pollution (Table 2).

Order Isopoda (Aquatic sow bugs).—Most freshwater sow bugs are restricted to springs, spring brooks, streams, and interstitial and subterranean waters but some may be found in ponds and lake shallows (Pennak 1989). Sow bugs are scavengers, eating dead and injured aquatic animals and both green and decaying vegetation. They are eaten by fish and may be parasitized by roundworms and Acanthocephala.

Sow bugs were found only in the Lagoons reach (Fig. 1 and Table 1). *Caecidotea* (*Asellus*) was identified at both NPS1 and 2, and *Lirceus* was identified at NPS1. Like scuds, sow bugs generally require high dissolved oxygen concentrations and are usually limited to clean, cold waters (Covich & Thorp 1991). Sow bugs are especially sensitive to copper and a number of other heavy metals. The Family Asellidae, which includes *Caecidotea* and *Lirceus*, has been used as an indicator of severe organic pollution (Table 2). Asellidae and *Caecidotea* have been rated quite tolerant of certain natural phenomena (Table 2). *Caecidotea* has been rated pollution-tolerant and moderately tolerant, and *Lirceus* has been rated slightly tolerant (Table 2).

Order Decapoda (Crayfish).—The order Decapoda, which includes a great diversity of marine, freshwater, and semiterrestrial crustaceans, is represented in North American fresh waters by freshwater shrimp and crayfish (Hobbs 1991). The 386 described species and subspecies of crayfish in North America are assigned to 12 genera in two families (Astacidae and Cambaridae); only Cambaridae occurs in this area. Crayfish are common inhabitants of a wide variety of freshwater environments, including running waters, shallows of lakes, ponds, sloughs, swamps, subterranean waters, and even wet meadows (Pennak 1989).

Crayfish (Family Cambaridae) were identified at two sites, NPS1 in the Lagoons reach and FWS3 in the USX reach (Fig. 1 and Table 1). Those found at NPS1 were identified as *Orconectes*. Channelization and siltation can be very detrimental to crayfish populations (Hobbs & Hall 1974). Although crayfish concentrations may increase with limited organic enrichment, organic pollution resulting in oxygen depletion will result in smaller populations of fewer species. Crayfish are highly sensitive to an increase in acidity (Hobbs 1991). Crayfish have been rated quite tolerant of some pollution, and Cambaridae have been rated somewhat pollution-tolerant (Table 2).

Subphylum Chelicerata
Class Arachnida

Subclass Acari (water mites).—Water mites were found at NPS2 in the Lagoons reach (Fig. 1 and Table 1). They were not identified any further than Acari (formerly Acarina). Water mites are excellent indicators of environmental quality; their diversity is greatly reduced in chemically polluted or physically disturbed habitats (Smith & Cook 1991). Water mites have been rated as quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Table 2).

Subphylum Uniramia
Class Insecta (insects)

Order Ephemeroptera (mayflies).—The mayflies all have aquatic larvae that may be found in streams, rivers, lakes, and temporary or permanent ponds and marshes (Hilsenhoff 1991). Almost all mayfly larvae are herbivores or detritivores, but a few species prey on other invertebrates; the adults do not feed. Often, mayfly larvae are an important food source for fish in streams. The three families of Ephemeroptera were found in the Grand Calumet River: Baetidae, Caenidae, and Heptageniidae. All three families are recognized as indicators of clean, unpolluted waters (Hilsenhoff 1991). Baetidae are found in a variety of streams, ponds, and lakes; Caenidae are similarly widespread. Heptageniidae are characteristic of streams, waveswept shores, and temporary ponds; they typically cling to rocks, wood, or debris (Hilsenhoff 1991).

Mayflies were found at NPS1 and 2 in the Lagoons reach and IDEM8 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Family Baetidae (small minnow mayflies) was represented by *Baetis* at NPS2 and IDEM8. The Family Caenidae (small squaregills) was represented by *Caenis* at NPS1 and 2. The Family Heptageniidae (flatheaded mayflies) was represented by *Stenonema* (*pulchellum* group) at IDEM8. Mayflies as a group are very important biological indicators for water quality because many species are very susceptible to water pollution or occur in predictable habitat types (McCafferty 1983).

Order Odonata (dragonflies & damselflies).—The odonates of North America are divided into two distinct suborders, Anisoptera (dragonflies) and Zygoptera (damselflies).

Dragonfly larvae were found at NPS1 and 2 in the Lagoons reach; FWS1, 3, 4, and 5 in the USX reach; and IDEM7 in the Lake George reach (Fig. 1 and Table 1). The Family Aeshnidae (darners) was collected at FWS1, 3, 4, and 5. The Family Corduliidae (green-eyed skimmers) was identified to *Neurocordulia* at NPS2 and *Tetragoneuria* at NPS1. The Family Libellulidae (common skimmers) was identified to *Erythemis* at IDEM7.

Most Aeshnidae larvae inhabit standing waters, especially weedy permanent ponds, marshes, and the shallows of lakes, and a few inhabit streams; Corduliidae also occupy stream debris, and Libellulidae are occasionally found along stream margins (Hilsenhoff 1991). Aeshnidae species have a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987), and as a group they have been rated moderately tolerant of certain natural phenomena, indicative of clean unpolluted streams (Table 2). Corduliidae has been considered indicative of clean unpolluted streams and some probable organic pollution, and *Neurocordulia* has been rated slightly pollution tolerant (Table 2). Many species of Libellulidae are very adaptable and tolerant of low dissolved oxygen concentrations or highly eutrophic habitats (McCafferty 1983). Libellulidae has been considered indicative of both clean, unpolluted streams and likely severe organic pollution, and *Erythemis* has been rated moderately tolerant of certain natural phenomena, somewhat pollution tolerant, and characteristic of natural conditions (Table 2).

Damselfly larvae were found in the Lagoons, USX, Gary Sanitary District, DuPont, Roxanna Marsh, East Chicago Sanitary District, and Federal Dredging Project reaches (Fig. 1 and Table 1). Unidentified damselflies were found at IDEM2, 3, 4, 5, and 6. The Family Coenagrionidae (narrow-winged damselflies) was identified to family at FWS3, 4, and 5; *Argia* at IDEM1, 3, 4, 5, and 7; *Chromagrion* at NPS1 and 2; and *Ischnura* at NPS1 and 2 and IDEM1, 2, 3, 5, 7, and 8. The Family Lestidae (spread-winged damselflies) was identified at FWS5.

Damselflies, especially *Ischnura*, can generally tolerate a wide range of chemical conditions, including high organic loading (Roback 1974). Coenagrionidae larvae live mostly in permanent ponds, marshes, swamps, and lake shallows, and occasionally in parts of streams with little or no current; some *Argia* species inhabit riffles of streams (Hilsenhoff 1991). Lestidae larvae commonly inhabit vegetation in permanent and temporary ponds and marshes, and occasionally may be found among vegetation in slow streams (Hilsenhoff 1991). They have been rated quite tolerant of certain natural conditions, indicative of clean, unpolluted streams, and indicative of likely severe organic pollution (Table 2).

Order Trichoptera (caddisflies).—The larvae and pupae of all but one or two species of caddisflies are aquatic (Hilsenhoff 1991). More than 1340 species are known in North America. Caddisflies occur in most types of freshwater habitats, including spring streams and seepage areas, rivers, lakes, temporary pools, and marshes (Wiggins 1984). Most larvae consume plant materials in some form, including algae and decaying plant tissue, and some are mainly predacious. Caddisflies are an important part of the stream community and may dominate the insect biomass (Hilsenhoff 1991). Many fish species feed on the larvae and emerging adults.

Caddisflies were found at NPS1 and 2 in the Lagoons reach, TAMS2 and IDEM3 in the Gary Sanitary District and DuPont reaches, IDEM6 in the East Chicago Sanitary District reach, IDEM7 in the Lake George reach, and IDEM8 in the Federal Dredging Project reach (Fig. 1 and Table 1). The Hydropsychidae (common netspinners) were identified to family at IDEM8, *Cheumatopsyche* at IDEM6 and 8, *Hydropsyche* at TAMS2, *Hydropsyche orris* (uncertain) at IDEM8, and *Hydropsyche simulans* at IDEM3 (pupae) and IDEM8. The Hydroptilidae (micro caddisflies) were identified to *Neotrichia* and *Orthotrichia* at NPS1. The Leptoceridae (long-horned casemakers) were identified to *Anthripsodes*, *Leptocerus*, *Nectopsyche*, and *Oecetis* at NPS2. The Polycentropodidae (trumpetnet and tubemaking caddisflies) were identified to *Cyrnellus fraternus* at IDEM3 and 7, and *Neureclipsis* at IDEM6. Caddisflies are very important in biological monitoring, due to the wide variation in pollution tolerance among species (Hilsenhoff 1991).

Hydropsychidae larvae inhabit streams of all sizes, currents, and temperatures; and most are omnivores, feeding on algae, crustacea, and insects (Hilsenhoff 1991). They, like other net-builders, are generally tolerant of organic loading but not of toxic pollutants (Roback 1974). Hydropsychidae has been rated quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Table 2).

Hydroptilidae larvae may be found in a wide variety of habitats and feed on algae and other plant material (Hilsenhoff 1991). They have been rated quite tolerant of certain natural phenomena and indicative of possible slight organic pollution (Table 2).

Leptoceridae larvae occur in a variety of permanent aquatic habitats (Hilsenhoff 1991). Most are omnivore-detritivores, but *Oecetis* species are predators, and some *Ceraclea* feed on freshwater sponges (McCafferty 1983). They have been rated somewhat tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Table 2).

Most Polycentropodidae larvae inhabit streams, but they also occur in a variety of other habitats (Hilsenhoff 1991). Most species are predators, but a few are herbivores. Polycentropodidae has been considered moderately tolerant of certain natural phenomena, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Table 2).

Order Hemiptera (water bugs).—Water bugs are remarkably diverse and occupy many different habitat types, including saline ponds, mountain lakes, hot springs, and large rivers (Polhemus 1984). Most species are predators; however, many genera of the water boatmen (Corixidae) are primarily collectors, feeding on detritus. They can be important predators of mosquito larvae and adults; however, some species bite people or eat small fish in hatcheries, thereby becoming a nuisance. Most water bugs seem to be resistant to predation, possibly due to their characteristic scent glands. However, the water boatmen are preyed upon by fish and used as food for pet fish and turtles.

Water bugs were identified at NPS1 and 2 in the Lagoons reach and FWS5 in the USX reach (Fig. 1 and Table 1). The Family Belostomatidae was identified to *Lethocerus* at NPS2. The Family Corixidae was identified to family at FWS5 and *Sigara* at NPS1. The Family Pleidae (pygmy backswimmers) was identified to *Plea* at NPS2. Water bugs are more tolerant of environmental extremes than most insects, except the water beetles and flies (Roback 1974).

Giant water bugs inhabit permanent standing water habitats (*Belostoma* and *Lethocerus*), especially weedy ponds, lake margins, marshes, or streams (*Abedus*), among aquatic plants, or under rocks in riffles (Hilsenhoff 1991). Giant water bugs have been rated moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Table 2).

Water boatmen are good water quality indicators in standing waters (Polhemus 1984). They are found in most permanent aquatic habitats and frequently in temporary ones as well (Hilsenhoff 1991). *Sigara* are notable as herbivores (McCafferty 1983). Water boatmen have been rated quite tolerant of certain natural phenomena and indicative of clean, unpolluted streams, and *Sigara* has been rated quite tolerant of certain natural phenomena (Table 2).

Pygmy backswimmers inhabit vegetation, primarily in permanent ponds but also in lake shallows, stream backwaters, and swamps (Hilsenhoff 1991). They feed on small invertebrates. Pygmy backswimmers are considered indicative of clean unpolluted streams (Table 2).

Order Coleoptera (water beetles).—Water beetles were found at NPS2 in the Lagoons reach, IDEM1 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). The Family Dytiscidae (predaceous diving beetles) was identified as *Dytiscus* at IDEM1 and *Laccophilus* at NPS2. The Family Gyrinidae (whirligig beetles) was identified as *Dineutus* at NPS2 and *Gyrinus* (uncertain) at IDEM6. The Family Haliplidae (crawling water beetles) was identified as *Haliplus* at NPS2. Water beetles are more tolerant of environmental extremes than most insects (Roback 1974). Both adults and larvae are predators, feeding primarily on other invertebrates and small vertebrates. They have been considered moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Table 2). *Dytiscus* has been considered moderately tolerant of certain natural phenomena, and *Laccophilus* has been considered pollution-tolerant (Table 2).

Whirligig beetles are widespread and often abundant (Hilsenhoff 1991). Larvae are predators, feeding mostly on other invertebrates; adults are scavengers on dead animals or predators of small invertebrates (White et al. 1984). They have been considered indicative of clean, unpolluted streams (Table 2). *Dineutus* has been considered slightly pollution-tolerant, and *Gyrinus* has been classified as pollution-tolerant (Table 2).

Crawling water beetles are often abundant in shallow, vegetation-choked habitats (Hilsenhoff 1991). Both larvae and adults are herbivores, feeding on algae or aquatic plants. They (and *Haliplus*) have been rated somewhat pollution-tolerant (Table 2).

Order Diptera (flies and midges).—*Biting midges (Family Ceratopogonidae):* Biting midge larvae live in a variety of aquatic habitats, including tree holes, marshes, swamps, ponds, lakes, and streams. Most larvae are carnivores, and others are herbivores or detritivores. Adults of some aquatic species feed on mammals; most others (including *Palpomyia*) feed on small insects (McCafferty 1983). Biting midges were found at NPS1 and 2 in the Lagoons reach, FWS5 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). They were identified to family at FWS5 and IDEM6, and to *Palpomyia* at NPS1 and 2. *Palpomyia* has been considered moderately pollution-tolerant, indicative of likely substantial organic pollution, and pollution-tolerant (Table 2).

Phantom midges (Family Chaoboridae): Phantom midges, so called because of the near-transparency of their larvae, inhabit a wide variety of standing waters, including lakes, permanent ponds, spring ponds, temporary ponds, and swamp margins (Hilsenhoff 1991). The larvae prey on small animals such as insect larvae and crustaceans; adults do not feed. Phantom midges were identified as *Chaoborus* at IDEM2 in the USX reach and INHS1 in the Federal Dredging Project reach (Fig. 1 and Table 1). In different sources, they have been rated moderately pollution-tolerant and indicative of clean, unpolluted streams, and *Chaoborus* has been rated indicative of very significant organic pollution (Table 2).

Midges (Family Chironomidae): Larvae of the Family Chironomidae, by far the largest family of aquatic insects, inhabit all types of permanent and temporary aquatic habitats (Hilsenhoff 1991). They are found under a wider range of environmental conditions than any other group of aquatic insects and often occur in high densities and diversity (Coffman & Ferrington 1984). Midge larvae have a wide variety of feeding habits, with herbivore-detritivores and carnivores all commonly represented; adults do not feed (Hilsenhoff 1991). The larvae and adults are fundamental to the diets of many other aquatic invertebrates, fish, and birds (Williams & Feltmate 1992).

Midges were found at all sites except TAMS2 in the Gary Sanitary District and DuPont reaches and the INHS sites in the Federal Dredging Project reach (Fig. 1 and Table 1). There were unidentified midge larvae at all FWS sites and all IDEM sites. Pupae were found at IDEM2, 3, and 5. The Subfamily Chironominae tribe Chironomini was identified to: *Chironomus*, *Chironomus decorus*, *Dicrotendipes* (= *Limnochironomus*), *Dicrotendipes nervosus*, *Glyptotendipes*, *Microtendipes*, *Parachironomus*, *Parachironomus abortivus*, *Phaenopsectra*, *Polypedilum*, *Polypedilum convictum*, and *Stenochironomus*. The Subfamily Chironominae (Tribe Tanytarsini) was identified to *Cladotanytarsus* and *Rheotanytarsus*. The Subfamily Orthocladiinae was identified to: *Cricotopus*, *Cricotopus bicinctus*, *Cricotopus intersectus*, *Cricotopus sylvestris*, *Eukiefferiella*, and *Eukiefferiella discoloripes*. The Subfamily Tanypodinae was identified to: *Ablabesmyia*, *Labrundinia*, *Procladius sublettei*, and *Thienemannimyia* group. Midge larvae have been used as biological water quality indicators because different species or species groups may be associated with different pollutants or environmental conditions (Williams & Feltmate 1992). As a group, they have been rated quite tolerant of certain natural phenomena and indicative of likely substantial organic pollution if they are not blood-red or likely severe organic pollution if they are blood-red (Table 2).

The Subfamily Chironominae includes species with various tolerances to pollution (Illi-

Table 2.—Examples of tolerance ratings for macroinvertebrates collected in the Grand Calumet River. Ranges of tolerance: USDA (1989) = 2–108; Illinois EPA (1985) = 0–11; Chutter (1972) = 0–10; Hilsenhoff (1988) = 0–10; Hilsenhoff (1987) = 0–10; Patrick & Palavage (1994) = P(ollution tolerant) or N(atural conditions). * Value dependent on number of Baetid Ephemeroptera.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Phylum Porifera						
Phylum Cnidaria	108					
Hydridae						
Hydra			6			N
Phylum Platyhelminthes						
Turbellaria	108	6	3			
Phylum Nematoda	108		7			?
Phylum Bryozoa						
Plumatella						
Phylum Annelida						
Oligochaeta	108	10	8 or 10*			
Lumbricidae	108					
Lumbriculidae						
Tubificidae	108					
Limnodrilus						P
Limnodrilus cervix						P
Limnodrilus hoffmeisteri						P
Potamothrix vejdovskyi						
Quistadrilus multisetosus						
Hirudinea	108	8	7			
Erpobdellidae		8				
Dina microstoma?						
Dina parva						P
Erpobdella punctata						P
Mooreobdella						
Mooreobdella fervida						
Mooreobdella microstoma						
Glossiphoniidae		8				
Helobdella						
Helobdella stagnalis						P

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Placobdella						
Phylum Mollusca						
Gastropoda	108		0			
Ancylidae			4			
Ferrissia		7				P
Hydrobiidae						
Amnicola		4				
Lymnaeidae	108					
Lymnaea	108	7				
Physidae	108					
Aplexa		7				
Physa	108	9				P
Physella						
Planorbidae	108					
Gyraulus		6				
Helisoma		7				P
Planorbula		7				
Promenetus						
Promenetus?						
Valvatidae						
Valvata		2				N
Bivalvia/Pelecypoda	108		0			
Corbiculidae		4				
Dreissenidae						
Sphaeriidae (unident.)						
Pisidium		5				P
Sphaerium		5				P
Phylum Arthropoda						
Branchiopoda						
"Cladocera"	108					
Amphipoda	108		0			
Hyalella	108	6			8	P
Isopoda	108		0			
Asellidae	108					

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Caecidotea/*Asellus*	108	6				P
Lirceus		4				
Decapoda	108		0			
Cambaridae	108	5				
Orconectes						
Arachnida						
Acari	108		0			
Insecta						
Ephemeroptera	72					
Baetidae	72		0	4		
Baetis	72	4				N
Caenidae	72		1	7		
Caenis	72	6			7	N
Heptageniidae	48		0	4		
Stenonema (*pulchellum* group)	48	3			3	N
Odonata, Anisoptera			0			
Aeshnidae	72			3		
Corduliidae				5		
Neurocordulia		3				
Tetragoneuria						
Libellulidae	72			9		
Erythemis	72	5				N
Odonata, Zygoptera			0			
Coenagrionidae	108			9		
Argia	108	5				N
Chromagrion						
Ischnura	72	6				
Lestidae	108			9		
Trichoptera			0			
Hydropsychidae	108			4		
Cheumatopsyche	108	6			5	N
Hydropsyche	108	5				N
Hydropsyche orris?		4			5	N
Hydropsyche simulans		5			7	

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Hydroptilidae	108			4		
Neotrichia	108	4			2	N
Orthotrichia		1	2			
Leptoceridae	54			4		
Anthripsodes						
Leptocerus		3				
Nectopsyche		3			3	N
Oecetis	54	5			8	N
Polycentropodidae	72			6		
Cyrnellus fraternus		5			8	
Neureclipsis		3			7	N
Hemiptera			0			
Belostomatidae	72					
Lethocerus	72					
Corixidae	108					
Sigara	108					
Pleidae						
Plea						
Coleoptera			0			
Dytiscidae	72					
Dytiscus	72					P
Laccophilus	72					
Gyrinidae	108					
Dineutus		4				
Gyrinus?	108	4				
Haliplidae	54					
Haliplus	54					
Diptera						
Ceratopogonidae	108	5	0	6		
Palpomyia		6			6	P
Chaoboridae		8	0			
Chaoborus					8	
Chironomidae	108			6 or 8 (red)		

Table 2.—Continued.

Taxa	USDA	Illinois EPA	Chutter	Hilsenhoff (1988)	Hilsenhoff (1987)	Patrick & Palavage
Chironominae						
(Chironomini)			7*			
Chironomus		11	10		10	P
Chironomus decorus						P
Dicrotendipes/Limnochironomus		6			8	N
Dicrotendipes nervosus		6				N
Glyptotendipes		10			10	
Microtendipes		6			6	
Parachironomus		8			10	P
Parachironomus abortivus						
Phaenopsectra		4			7	
Polypedilum		6			6	P
Polypedilum convictum						P
Stenochironomus		3			5	N
(Tanytarsini)			0			
Cladotanytarsus		7			7	P
Rheotanytarsus		6			6	P
(Orthocladiinae)			7*			
Cricotopus		8			7	
Cricotopus bicinctus		10				P
Cricotopus intersectus						
Cricotopus sylvestris						
Eukiefferiella		4			8	N
Eukiefferiella discoloripes						
(Tanypodinae)			0			
Ablabesmyia		6			8	P
Labrundinia		4			7	
Procladius sublettei		8			9	N
Thienemannimyia group		6				N
Culicidae	108	8	10			
Tipulidae	72	4	0	3		
Empididae	108	6	0	6		
Stratiomyidae	108		0			
Syrphidae	108	11	0	10		

nois EPA 1985; Hilsenhoff 1987). Of the Chironomini genera found in these studies, *Chironomus* has been rated the most tolerant and *Stenochironomus* the least (Table 2). The tribe Tanytarsini has been used to indicate clean, unpolluted waters (Table 2). *Cladotanytarsus* has been rated moderately pollution-tolerant, indicative of significant organic pollution, and pollution-tolerant (Table 2). *Rheotanytarsus* has been rated moderately pollution tolerant, indicative of fairly significant organic pollution, and pollution-tolerant (Table 2).

The Subfamily Orthocladiinae contains species with a wide range of pollution tolerances (Illinois EPA 1985; Hilsenhoff 1987). It has been given a sliding scale of tolerance values by Chutter (1972) with the values dependent on the diversity and abundance of Baetid mayflies; in these studies, the subfamily indicates organically-enriched to polluted waters. *Cricotopus* has been rated moderately pollution-tolerant and indicative of significant organic pollution, and *Cricotopus bicinctus* has been rated very pollution-tolerant, indicative of severe organic pollution, and pollution-tolerant (Table 2). *Eukiefferiella* has been rated slightly pollution-tolerant, indicative of very significant organic pollution (Table 2).

The Subfamily Tanypodinae also contains species with a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987). It is considered indicative of clean unpolluted streams (Table 2). *Ablabesmyia* has been rated moderately pollution-tolerant, indicative of very significant organic pollution, and pollution-tolerant (Table 2). *Labrundinia* has been rated slightly pollution-tolerant and indicative of significant organic pollution (Table 2). *Procladius* has been rated moderately pollution-tolerant, indicative of severe organic pollution (Table 2). *Thienemannimyia* group has been rated moderately pollution-tolerant and characteristic of natural conditions (Table 2).

Mosquitoes (Family Culicidae): Mosquito larvae were identified at IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). Mosquito larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, and indicative of organically-polluted streams (Table 2).

Crane flies (Family Tipulidae): Crane fly larvae were common at IDEM6 in the East Chicago Sanitary District reach (Fig. 1 and Table 1). Crane fly larvae have been rated moderately tolerant of certain natural phenomena, slightly pollution-tolerant, indicative of unlikely organic pollution and of clean unpolluted waters (Table 2).

Dance flies (Family Empididae): One dance fly larva was found at FWS5 in the USX reach (Fig. 1 and Table 1). It was identified only to family. Dance fly larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Table 2).

Soldier flies (Family Stratiomyidae): Soldier fly larvae were identified at FWS4 in the USX reach (Fig. 1 and Table 1). They were not identified beyond family. Soldier fly larvae have been considered quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and pollution-tolerant (Table 2).

Rat-tailed maggots/flower flies (Family Syrphidae): Rat-tailed maggots inhabit shallow standing waters or margins of running waters, especially areas high in decomposing organic matter (Hilsenhoff 1991). Because of their very long breathing tube, rat-tailed maggots are able to inhabit very polluted, low-oxygen areas such as sewage lagoons. Rat-tailed maggots were found at FWS4 in the USX reach (Fig. 1 and Table 1). Rat-tailed maggots have been rated as very pollution-tolerant, indicative of likely severe organic pollution (Table 2).

SUMMARY AND RESTORATION POSSIBILITIES

Current macroinvertebrate habitats in the Grand Calumet River and Indiana Harbor Canal are degraded, as is evident by the resident communities. In all reaches other than the Lagoons reach, aquatic earthworms and other pollution-tolerant organisms are dominant, and the more sensitive taxa are either scarce or non-existent, which suggests a highly degraded habitat (Tables 1, 2). The Lagoons reach appears to be less affected, probably because the lagoons are located above industrial and sanitary outfalls (IDEM 1991). This reach is somewhat degraded, however, particularly the West Lagoon where the macroinvertebrate community appears to be stressed by extremely high ammonia levels (Hardy 1984).

So many changes have occurred over the Grand Calumet River's history that it may be nearly impossible for it to return to its presettlement state. However, there are several ways to improve the river's habitat quality and bring back a healthier and more diverse macroinvertebrate population. Different approaches for restoring the various reaches will depend primarily on reach-specific factors other than macroinvertebrate community composition.

In-place sediment clean-up.—First, the problem of contaminated sediments must be addressed. Grand Calumet River and Indiana Harbor Canal sediments are known to be contaminated by a wide variety of pollutants, including nutrients, organic matter, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and high concentrations of metals (USACE 1994a). Contaminated sediment can impact macroinvertebrates in a number of ways—directly, as a living and foraging area and food source, and indirectly, as a source of water and prey contamination and oxygen depletion. Improving sediment quality will be necessary to restore macroinvertebrate habitat in the Grand Calumet River, and one way to achieve this is by cleaning up the contaminated sediments.

Sediment clean-up options include removal (dredging), capping with clean materials, and in-place treatment. Although it is theoretically feasible, not enough is known about in-place treatment (e.g., fixation/solidification or biodegradation) to consider it seriously at this point (USACE 1994a). Dredging—the excavation of bottom sediments from a waterway—may be performed with a variety of equipment (USACE 1994b). The two basic types of dredges are mechanical dredges, which remove sediments using a large bucket or shovel, and hydraulic dredges, which remove and transport the sediments in water slurry. The particular method selected depends on reach-specific factors that will not be discussed here.

The positive impacts of dredging on the aquatic macroinvertebrates, provided that it would remove the total depth of contaminated sediments, would be the removal of the contaminants (and thus their direct and indirect negative impacts) from the system, and the uncovering of uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls (see below). Removing only part of the contaminated sediments would be of little benefit unless water depth was maintained with capping.

The negative impacts of dredging would include the removal of existing benthic macroinvertebrates and rooted vegetation, changes in channel morphology, and temporary, localized degradation of water and habitat quality. Although little can be done about removing the benthic community, it is a degraded community. Further, the newly exposed-sediments would be recolonized and revegetated over time. The other negative impacts could be minimized by taking certain steps during and after dredging. The placement of weirs up- and downstream of the dredging operation would help maintain water flow and surface levels and could localize turbidity during dredging. Digging the channel too deep or the banks too steep would encourage the re-establishment of rooted vegetation and minimize flow pattern changes and riverbank sloughing. In reaches where the contaminated sediment is quite deep or the river is already too channeled, the bottom could be filled with clean sediment.

Capping is the covering of contaminated sediment by clean materials (USACE 1994a). The contamination remains in the waterway, but its availability to the water column and aquatic life is reduced. The cap must isolate sediment contamination from the overlying water, prevent penetration by benthic or burrowing organisms, and be resistant to scour. Cap design depends on various factors, including the hydraulic system, sediment characteristics, and types of contamination. One concern with leaving the sediment in place is that groundwater may still interact with the contaminants.

The positive impacts of capping on the aquatic macroinvertebrates, provided that it would isolate and stabilize the contaminated sediments, would be the removal of the possibility of direct and indirect negative impacts from the contaminants and the availability of new, uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls.

The negative impacts of capping would include the covering of existing benthic macroinvertebrates and rooted vegetation and possible adverse habitat impacts due to water depth reduction in shallow areas. Although little could be done about the first impact, the macroinvertebrate communities that would be buried are degraded, and the newly-exposed sediments would be recolonized and revegetated over time. In shallow areas, partial dredging prior to capping could compensate for water depth loss.

Sediment source controls.—Source controls, which reduce the quantity and contamination level of sediments entering the river, will be very important in improving sediment quality and macroinvertebrate habitat in the Grand Calumet River and Indiana Harbor Canal. If done properly, they may only impact the macroinvertebrate communities positively. Reductions in the quantity of sediment entering the river would improve habitat by decreasing siltation and turbidity, both of which can be detrimental to some macroinvertebrates. Without reductions in contamination levels of sediments entering the river, sediment clean-up would only provide a temporary solution, since uncontaminated sediment would simply be covered and replaced by more contaminated sediment (USACE 1994a).

There are three major sources of sediments to the Grand Calumet River and Indiana Harbor Canal: municipal and industrial point discharges, combined sewer overflows (CSOs), and urban runoff. Point sources include three municipal wastewater treatment plants and over 40 outfalls for discharges from industries and manufacturers. Over 90% of the system's dry-weather flow originates as treated municipal and industrial wastewater (McCown et al. 1976). Point discharges are regulated under the Clean Water Act (NPDES permit program); effects of this regulation can be seen in the 56% reduction of suspended solids loadings from point sources between 1974–1984 (USACE 1994a). The Remedial Action Plan (RAP) calls for full compliance of all NPDES discharges and the resolution of enforcement actions against violators (IDEM 1991).

Combined sewer overflows are not as easily controlled as point discharges (USACE 1994a). CSOs result from heavy rainfall events increasing flow in a combined sewer system so that it exceeds the capacity of the sewer or the wastewater treatment plant. This causes a mixture of stormwater and raw sewage to be discharged directly to the river. Possible solutions to CSOs include separating sewers into sanitary and storm sewers and constructing a detention basin or tunnel for temporary storage of combined sewer flows during storms for later treatment and discharge. The NPDES permits with the sanitary districts of East Chicago, Hammond, and Gary would have to be modified by IDEM to require satisfactory maintenance and operation of the combined sewer systems.

Urban runoff is the most difficult source to control (USACE 1994a). Approximately 47% of the Grand Calumet River watershed east of the Illinois/Indiana border is occupied by heavy industry, while only 7.6% is open space (Ketcham et al. 1992). Measures for controlling the amount of sediment released into the river in stormwater (other than making large changes to the existing land-use practices) include detention basins, retention devices, constructed wetlands, vegetative controls, construction erosion controls, and source controls (e.g., street sweeping and protection of stockpiled materials from rainfall).

Sediment transport controls.—Transport controls reduce the resuspension and transport of sediments that have already been deposited on the river bottom. Reductions in sediment resuspension and transport would improve macroinvertebrate habitat by reducing turbidity, erosion, and the exposure of the organisms and the water column to sediment contaminants (USACE 1994a). Sediment impacts on water quality and aquatic organisms are directly related to the sediment surface area exposed; and when sediments are in suspension, surface area is greatly increased. Sediment resuspension could be reduced by changing the hydrology and hydraulics of the river and canal or by controlling physical disturbances that cause resuspension, such as boat traffic and dredging.

Due to the effects of urbanization on the Grand Calumet River watershed, stormwater flows in the river can be much greater than normal flows, resulting in scouring and resuspension of sediments. In addition to the other ecological problems created by these high flows, they could make capping of contaminated sediment more difficult or infeasible, since the capping material may be washed downstream (USACE 1994a). Many of the same methods mentioned above for decreasing sediments in urban runoff and CSOs would also reduce peak storm flows.

Another method that has been used to control sediment transport is a sediment trap or settling basin (USACE 1994a). A deepened channel or basin is excavated within a waterway to catch sediments from upstream, and the sediments are then dredged and disposed nearby. This practice is useful for preventing deposition in a high quality reach, and it is more cost-effective than removing sediments from a long stretch of river.

Water quality improvement.—Historically, the Grand Calumet River and Indiana Harbor Canal have been plagued with water quality problems, including low oxygen levels and high levels of ammonia, total dissolved solids, total phosphorus, chlorides, fluorides, sulfates, oil and grease, bacteria, cyanide, metals, and PCBs (IDEM 1991). Although most of these parameters have improved, many still exceed applicable water quality standards. Improving the water quality of the waterway would also better the health of its macroinvertebrate community.

The sources of water pollution to the Grand Calumet River and Indiana Harbor Canal include municipal and industrial point discharges, CSOs, urban runoff, air deposition, groundwater contamination, and contaminated sediments (IDEM 1991; USACE 1994a). The first three of these are also major sediment sources and are described more fully in the previous section. The NPDES permit program regulates pollutants in point discharges. In general, methods used to decrease the quantity and contamination level of sediments entering the river from CSOs and urban runoff would also decrease the input of other water-borne contaminants.

Air deposition includes both wet deposition, which is precipitation of any type, and dry deposition, which is the settling of dry particles from the air. Because the area is highly industrialized, air deposition may be an important source of contaminants to the Grand Calumet River and Indiana Harbor Canal. Northwest Indiana has the highest levels of precipitation-borne lead in the Great Lakes region (Gatz et al. 1989), and Indiana Dunes National Lakeshore has the highest levels of precipitational sulfate and nitrate of any monitored national park unit in the country (NADP 1993). Both direct and indirect deposition to the river and canal could be decreased through better emissions controls, and indirect deposition could be decreased by many of the same methods used for decreasing sediment levels in urban runoff and CSOs.

Groundwater contamination may be another source of water pollution to the Grand Calumet River and Indiana Harbor Canal. Analysis of water samples taken from 128 wells in the Calumet Region indicated that groundwater quality has changed in parts of the study area as a result of industrialization and urbanization (Duwelius et al. 1996). The largest concentrations of trace elements and organic compounds were detected in samples from wells located in or near industrial areas or areas of waste disposal. A total of 14 volatile organic compounds, 23 semivolatile organic compounds, and 18 pesticide compounds were detected in 20, 56, and 29 of the samples, respectively. Compounds containing PCBs were detected in water from three of the wells.

Contaminated sediments can have a significant impact on water quality by acting as a source for nutrients and contaminants and as a sink for dissolved oxygen (USACE 1994a). Brannon et al. (1989) found that the overall transport and migration of sediment contamination in the Grand Calumet River and Indiana Harbor Canal was influenced by the following factors in descending order of importance: transport of contaminants associated with particulates, transport of contaminants desorbed from resuspended particulates, and transport of soluble contaminants released from deposited sediment. Release of contaminants from deposited sediment is the least important factor because sediments have a much greater exposed surface area when suspended, and the exposed surface area directly affects the release of contaminants, as well as the release of nutrients and the rate of oxygen demand (USACE 1994a). In-place sediment clean-up, sediment source controls, and sediment transport controls would all help to improve the water quality of the Grand Calumet River and Indiana Harbor Canal.

The river corridor.—Restoration of the Grand Calumet River and its macroinvertebrate populations must involve more than the river itself. The river is just one part of the larger ecosystem, and its health is related to the health of all other parts. There are several important natural habitat areas along the river corridor, such as Miller Woods in the Lagoons reach and Clark and Pine East Nature Preserve in the USX reach, that need to be preserved and protected. Wetlands and riparian areas need to be restored and protected wherever possible. The impacts of restoration alternatives, particularly sediment clean-up options, must be considered for the whole system rather than for the river alone. In some areas, such as the East Lagoon, it may be preferable to leave the contaminated sediments in place rather than risk damaging the surrounding natural area with dredging and disposal activities.

The challenge.—The greatest challenge will be to restore the Grand Calumet River and Indiana Harbor Canal to their best possible ecological health given the various social, economical, and political constraints. Restoration would require the cooperation of federal and state agencies, local governments, industries, municipal wastewater treatment plants, and the public; and many compromises would be necessary. Industrial and residential development have severely altered the landscape and the river itself, yet there remains a great potential for improving the health of the river and the whole ecosystem.

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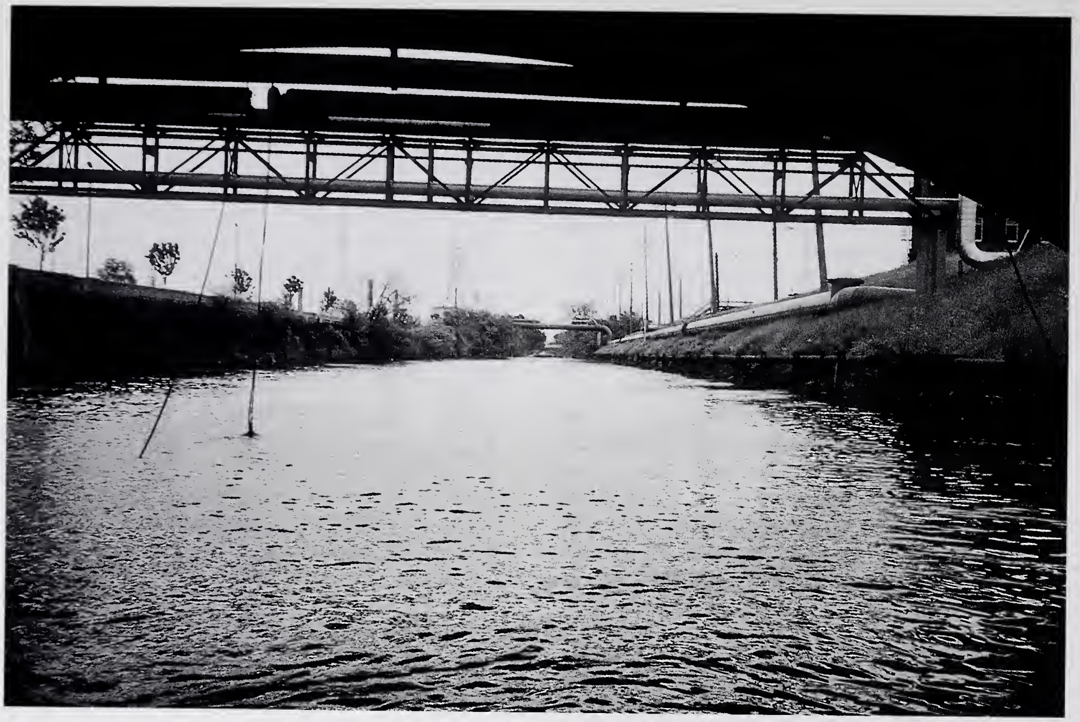

In addition to transportation crossings, the areas around the Grand Calumet River are heavily used by industry. Pipelines run along much of its length and across the channel. The banks have been heavily modified in order to maintain industrial equipment.

Gradually sloping banks have been sharply inclined along much of the river where the bank has been cut back to widen the channel and protect industrial pipelines. This greatly impacts drainage and natural vegetation.

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PAST, PRESENT AND POTENTIAL OF FISH ASSEMBLAGES IN THE GRAND CALUMET RIVER AND INDIANA HARBOR CANAL DRAINAGE WITH EMPHASIS ON RECOVERY OF NATIVE FISH COMMUNITIES

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ABSTRACT. The fish community of the Grand Calumet River has shown some recovery during the 1990s; however, the community has not recovered to 1900 levels. The fish community is dominated by tolerant detritivores, which are exotic or non-indigenous species. These species are capable of surviving low dissolved oxygen levels, contaminated sediments and subchronic toxicity from surface water effluents. The East Branch Grand Calumet River has the highest species richness and highest biological integrity among the Grand Calumet River sites. The Grand Calumet Lagoons, which were the former mouth of the river, still possess sensitive species including Iowa darter and lake chubsucker. Little biological integrity remains in the West Branch Grand Calumet River, with several collecting events finding "no fish." Despite the recent finding of salmon in the river, optimistically we should not assume that the river has recovered. Biological integrity scores show that the communities possess "poor" to "very poor" integrity levels, while average index scores for the past decade differed by less than 5 integrity points. Tissue consumption advisories show high contaminant levels of PAHs, mercury and inorganic metals, while others have found high levels in adjacent landfill sites. Full restoration efforts should include reducing contaminant levels in tissues, removal of contaminated sediments, physical habitat recovery of dissolved oxygen, reducing thermal profiles, increasing macroinvertebrate forage and increasing heterogenous substrates in low habitat diversity areas. Furthermore, re-creation of littoral habitat, side bank wetlands to serve as nursery habitat, and creation of braided channels could enhance fish community use of the Grand Calumet River watershed.

Keywords: Grand Calumet River, fish, area of concern, habitat restoration

The structure and function of the Grand Calumet River-Indiana Harbor Canal fish community have undergone drastic changes since the turn of the century (Meek & Hildebrand 1910; Shelford 1937; CDM/Limnetics 1976; Polls & Dennison 1984; Simon et al. 1989; Simon & Stewart 1999; Simon et al. 2000; Simon et al. in press). Changes in stream depth, water quality and land use eliminated indigenous species during the middle of the century (Meek & Hildrebrand 1910; Shelford 1937). Dredging and channelization altered the stream from a riverine wetland to a narrow channel and significantly increased the flow velocity (U.S. Environmental Protection Agency (EPA) 1985). During the early 1970s, few, if any, species of fish were documented in either the East or West Branches of the Grand Calumet River (CDM/Limnetics 1976; Polls & Dennison 1984; F. Lee Bridges, Indiana Department of Environmental Management pers. comm.). Young-of-the-year of lake-dwelling transient species were present only seasonally in the Indiana Harbor Canal (CDM/Limnetics 1976). Subchronic toxicity was documented at a few of the major dischargers to the system (Simon 1989; Hoke et al. 1993).

Documented improvements in water quality and the fish community during the 1990s suggest that there is a possibility of restoring the Grand Calumet River (Crawford & Wangsness 1987; Simon & Stewart 1999; Simon et al. 2000). The purpose of this study was to document the past, present and future recovery potential of the Grand Calumet River and Indiana Harbor Canal fish community.

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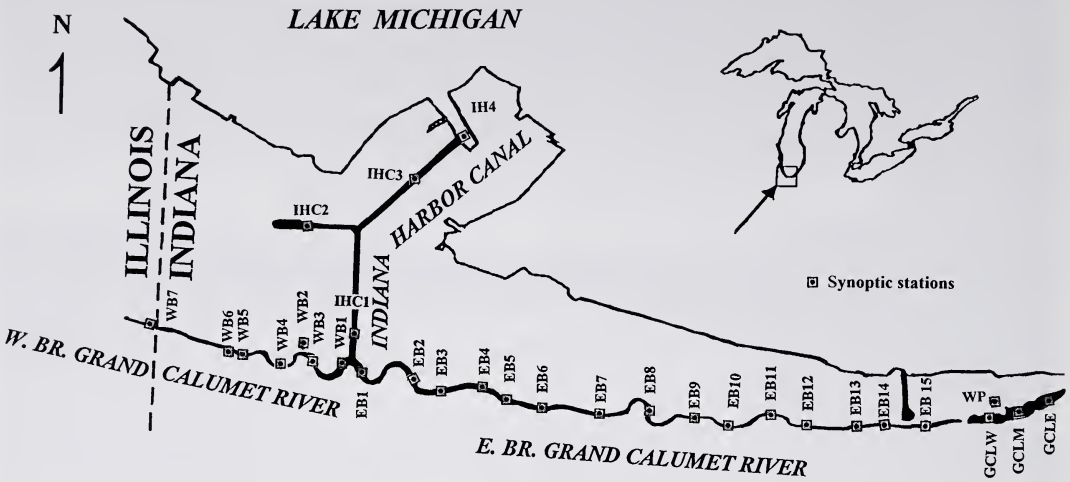

Figure 1.—Study sites collected in the Grand Calumet River and Indiana Harbor Canal between 1976 and 1998. *Abbreviations:* EB = East Branch Grand Calumet River, WB = West Branch Grand Calumet River, IHC = Indiana Harbor Canal, IH = Indiana Harbor, GCL = Grand Calumet Lagoons and WP = West Pond. Numbers refer to collection localities referred to in the text and summarized in Tables 3–6.

STUDY AREA DESCRIPTION

The Grand Calumet River basin is a small watershed located in northwestern Indiana (Fig. 1) and encompasses about 17,500 ha contained almost entirely within Lake County, Indiana (USEPA 1985). The Grand Calumet River, about 34 km in length, has been designated an Area of Concern by the International Joint Commission (IJC 1989; IDEM 1988). The Grand Calumet River and Indiana Harbor Canal occupy a low-relief area in the glacial bed of geological Lake Chicago. The general flow is sluggish and westward in the East Branch Grand Calumet River, east- or westward in the West Branch depending on Lake Michigan levels, and northward in the Indiana Harbor Canal, an artificial connection to Lake Michigan.

The river reaches discussed here include: 1) East Branch, Tennessee Street (EB15), East Broadway (EB14), USX-West Broadway (EB13), USX downstream triple railroad tressle (EB12), West Buchanan Street (EB11), East Buchanan Street (EB10), East Bridge Street (EB8), East of Bonji (EB7), west of Clark Road (EB6), East Cline Avenue (EB5), West Cline Avenue (EB4), East Kennedy Avenue (EB3), west of Kennedy Avenue (EB2), the mouth of the East Branch (EB1); 2) West Branch, mouth of the West Branch (WB1), East Chicago Sanitary District earthen channel (WB2), East Indianapolis Boulevard (WB3), Roxanna Marsh and West Indianapolis Boulevard (WB4), East Columbia Avenue (Hammond; WB5), Culverts (WB6), and Far West including sites in Illinois (WB7); 3) Indiana Harbor and Canal, Federal Channel including the harbor mouth and breakwater, anchor and manaevering basin, canal entrance (IH4), Dickey Road and section lakeward of the forks (IHC3), Lake George (IHC2), and Columbus Avenue and Canal(IHC1); and the 4) Grand Calumet Lagoons, Eastern Lagoon (GCL1), Middle Lagoon (GCL2), and Western Lagoon(GCL3).

STATUS OF FISH COMMUNITIES

Sampling in the Middle and Western Lagoons, the former mouth of the Grand Calumet River, has revealed the presence of several sensitive indicator species, including the lake chubsucker (*Erimyzon sucetta*) and Iowa darter (*Etheostoma exile*). The Middle Lagoon has been isolated from much of the degrading influences found throughout the rest of the river basin (Simon & Stewart 1998). The presence of these species in the Middle Lagoon suggests that sensitive species once existed in the Grand Calumet River. Currently, the fish communities of the remainder of the Grand Calumet River exhibit "poor" to "very poor" biological integrity. The biological integrity of the fish community in the East Branch of the Grand Calumet River is substantially better than in the West Branch. The lower integrity score in the West Branch is due primarily to biosolid impacts in the vicinity of Columbia Avenue and the resulting depletion of dissolved oxygen in a substantial reach of the river as it flows towards Illinois. Roxanna Marsh and areas to the east have low water depths and contaminated sediments, and they are impacted by municipal sewage treatment plant discharges from the cities of East Chicago and Hammond.

The fish community varies along the length of the East Branch of the Grand Calumet River and is affected by effluent quality, water quantity and sediment quality (Crawford & Wangsness 1987). Past reduction in effluents and combined sewer overflows, closure of point sources and removal of contaminated sediments in the upper 10 miles (18 km) of the East Branch have improved the diversity and integrity of the fish community. Fish communities near Cline Avenue bear some resemblance to the fish community that should be supported by the habitat, but they exhibit severely altered community function.

The Indiana Harbor Canal is a man-made connection between the Grand Calumet River and Lake Michigan. The habitat in the Indiana Harbor Canal can be divided into the Lake Michigan breakwall border and turning basin and the Lake George channels. Improvements in fish community diversity in the Indiana Harbor Canal can be directly attributed to the removal of contaminated sediments. This allowed opportunistic, transient young-of-the-year of lake dwelling species to use portions of the detrital food base. Unfortunately, redistribution of contaminated materials and the increase in the population number and abundance of alien species has compromised the recovery of the nearshore zone of Lake Michigan along the breakwalls (Simon et al. 1998). The European round goby (*Neogobius melanostomus*) has been documented from the breakwall. Water and habitat quality improvements will facilitate expansion of round goby populations, which pose a serious threat to indigenous species such as mottled sculpin (*Cottus bairdi*) and johnny darter (*Etheostoma nigrum*).

Early studies of fish in the Grand Calumet River examined basic distribution, ecology and natural history of the communities. A number of studies were completed between the turn of the century and 1945. Meek & Hildebrand (1910) studied the distribution of fish within 50 miles (92 km) of Chicago. Seth Meek, a former student of David Starr Jordan, Indiana University, became curator of fishes with the Columbia Museum of Natural History (now called the Field Museum of Natural History). He and Samuel Hildebrand produced one of the first documented inventories of Grand Calumet River species. It is not clear whether Victor Shelford (1937), an early ecologist from the University of Chicago, actually sampled the Lagoons of the Grand Calumet or whether he simply used the data of Meek and Hildebrand. The species lists in the two papers are so similar that it seems likely they are drawn from the same data. No further fish sampling efforts were conducted in the Grand Calumet River during this period. Gerking (1945) did not specifically sample the Grand Calumet River while completing his epic evaluation of the distribution of Indiana fish, but he did summarize previously published distribution records and changes in nomenclature. Species distribution in the Grand Calumet River was not further studied until collaborative efforts between Indiana Department of Environmental Management and the U.S. Environmental Protection Agency were started during the mid-to late-1980s. This effort resulted in a published study of three years of intensive collection (Simon et al. 1989). Prior to 1985, the collection of fish from the Grand Calumet River was considered a futile effort because either few or no fish species would be collected after extensive sampling effort (C. Lee Bridges (IDEM) pers. comm.).

Extensive monitoring and assessment has been completed during the last decade (Simon et al. 1989; Simon 1991; Sobiech et al. 1994). The Indiana Department of Environmental Management has conducted annual sampling to assess and evaluate fish consumption advisories (IDEM 1997). The U.S. Army Corps of Engineers has been sampling the Indiana Harbor Canal breakwall for several years to gather data on changes in the nearshore fish communities of Lake Michigan. The U.S. Environmental Protection Agency has rigorously sampled the East and West Branches of the River to assess point source dischargers (Simon 1989; Simon et al. 1989; Sobiech et al. 1994).

STATUS OF THE GRAND CALUMET RIVER FISHES PRIOR TO 1970

Changes in the fish community of the Grand Calumet River are a direct result of the flow alteration during the early-to-mid 1800s. Prior to these alterations, the Grand Calumet was comprised of palustrine wetlands, a series of shallow pools connected by narrow flowages between pools (Moore 1959). These pools and flowages enabled movement of species between Lake Michigan and the important wetland nursery and spawning habitat provided by the slow-flowing river. Shelford (1937) compared the physical status of the Grand Calumet River to other Lake Michigan tributaries such as the lower St. Joseph River, Michigan; lower Galien River, Michigan; and Dead River, Illinois. Although Shelford did not specifically describe the condition of the Grand Calumet River, the river certainly possessed characteristics similar to the other streams he mentioned.

These rivers characteristically have fine sand or fine organic sediments with little or no rock. The rivers originate in wetland habitats characterized by emergent rooted macrophytes. Differentiation of pools and riffles is not common. Instead, deep pools and narrow, shallow connections (termed flowages) enable passage of water between pools. The flow of water is mostly determined by the depth of Lake Michigan and reflects annual climatologic and hydrologic conditions. The deeper portions of these streams support rooted aquatic macrophytes such as (*Potemogeton* sp.) and water lilies (*Nuphar* and *Nelumbo*). Bulrushes (*Scirpus* sp.) and cattails (*Typha*) line the shore and the banks along back bays and side channels.

Meek & Hildebrand (1910) evaluated the distribution of fish species within a 50 mile (92 km) radius of Chicago and indicated that as many as 22 species occurred in the Grand Calumet River drainage (Table 1). Shelford documented 12 species of fish during 1909, including species such as blacknose shiner, lake chubsucker, northern pike, redhorse, and tadpole madtom (Table 2). The Dead River (Illinois) has a much smaller drainage area than the Grand Calumet River; but unlike the Grand Calumet River, Dead River has not been extensively modified. The Dead River is a designated nature preserve contained within the Illinois Beach State Park near Zion, Illinois, which is one of the few remaining areas of dune and swale topography in Illinois. In 1996, 14 species were captured in the Dead River, six of which were present in the 1909 sample. Of the 20 total species collected from the Dead River during the two events, fewer than 30% were found in both 1909 and 1996.

Table 1.—The fish collected from the Grand Calumet River drainage and deposited in the Field Museum of Natural History by Meek & Hildebrand (1910). Specimens were collected near the former mouth, Clarks junction, Gary, and from the Lagoons.

Bowfin	*Amia calva*
Carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
White sucker	*Catostomus commersoni*
Channel catfish	*Ictalurus punctatus*
Black bullhead	*Ameiurus melas*
Yellow bullhead	*Ameiurus natalis*
Brown bullhead	*Ameiurus nebulosus*
Tadpole madtom	*Noturus gyrinus*
Northern pike	*Esox lucius*
Grass pickerel	*Esox americanus*
Central mudminnow	*Umbra limi*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Logperch	*Percina caprodes*
Freshwater drum	*Aplodinotus grunniens*

Until the 1960s, the Grand Calumet River suffered from chemical and physical degradation caused by municipal and industrial pollution. Untreated sewage and waste from packing plants and heavy industry eliminated most of the natural aquatic communities. Surveys of the river during the early 1960s found only 20–108 oligochaetes/m^2 in the mouth of the Indiana Harbor Canal. By the early 1970s, the abundance of oligochaetes had increased to 2400–500,000/m^2. The increase in biomass was considered sufficient to support native fish populations; however, it reflected extensively disturbed habitat.

ASSESSMENT OF SUBCHRONIC TOXICITY

Water quantity is largely determined by effluent discharged into the Grand Calumet Riv-

Table 2.—The fish species collected in the Dead River, Illinois Beach State Park, Illinois, in 1909 (Shelford 1937) and 1996 (Moy & Simon unpubl. data).

Common name	Species name	1909	1996
Gizzard shad	*Dorosoma cepedianum*		●
Grass pickerel	*Esox americanus*	●	
Northern pike	*Esox lucius*	●	●
Redhorse	*Moxostoma* sp.	●	
Lake chubsucker	*Erimyzon sucetta*	●	
Common shiner	*Luxilus cornutus*	●	
Golden shiner	*Notemigonus crysoleucas*	●	●
Emerald shiner	*Notropis atherinoides*		●
Spottail shiner	*Notropis hudsonius*		●
Blacknose shiner	*Notropis heterolepis*	●	●
Bluntnose minnow	*Pimephales notatus*	●	
Tadpole madtom	*Noturus gyrinus*	●	
Pumpkinseed	*Lepomis gibbosus*		●
Warmouth	*Lepomis gulosus*		●
Bluegill	*Lepomis macrochirus*	●	●
White crappie	*Pomoxis annularis*	●	●
Black crappie	*Pomoxis nigromaculatus*		●
Smallmouth bass	*Micropterus dolomieu*		●
Largemouth bass	*Micropterus salmoides*	●	●
Yellow perch	*Perca flavescens*		●
	Total taxa	12	14

er. During low flow conditions, over 90% of the Grand Calumet River originates as industrial wastewater, industrial cooling and process water, stormwater runoff and municipal effluent (Crawford & Wangsness 1987). Noncontact cooling water comprises the majority of the industrial effluent. A total of 39 permitted discharge outfalls and 14 combined sewer overflow points are located along the river (U.S. Environmental Protection Agency 1984; Custer et al. 1996).

In the document entitled "Masterplan for Improving the Water Quality of the Grand Calumet River and Indiana Harbor Canal," the U.S. Environmental Protection Agency (1985) identified slow flowing water, low dissolved oxygen and sedimentation as factors limiting the habitat quality of the Grand Calumet River. In the 305(b) Report to Congress for 1992–1993, the Indiana Department of Environmental Management suggested a lack of forage, low dissolved oxygen and toxic stresses caused the unstable fish community in the Indiana Harbor Canal and Grand Calumet River. IDEM classifies the Grand Calumet River as supporting "limited aquatic life." This use designation indicates the degraded condition of the aquatic environment; the Grand Calumet River is one of the only streams in Indiana with this designation.

The high organic content, consequent high oxygen demand and resultant habitat degradation in the West Branch are evidence of previous bypass events and combined sewer overflow (CSO) discharges. Point source discharge violations in the Grand Calumet River watershed include untreated sewage and NPDES permit violations.

Simon (1989) evaluated the impact of 19 major point source dischargers along the Grand Calumet River and the Indiana Harbor Canal in 1986. Preliminary screens were used to evaluate the potential effects on fathead minnow (*Pimephales promelas*) embryos and newly-hatched larvae. Three subchronic endpoints were evaluated, including percent hatching, survival and teratogenicity. Each outfall was compared to a laboratory control population using Lake Michigan drinking water. Six preliminary positive test results were confirmed in a retest using a dilution series of 100, 77.5, 42.4, 30.0 and 17.3% solutions.

Hammond Sanitary District effluent produced a significant teratogenic response during the preliminary test but did not reduce survival of larvae. A single USX (steel industry) outfall produced positive results during the screening procedure but could not be resampled due to a plant shutdown in 1986. The East Chicago Sanitary District effluent did not elicit a chronic response for hatching or survival during definitive testing; however, statistically significant teratogenic responses were observed in larvae in all dilutions tested. Effluent from Inland Steel outfalls 008 and 014 produced a chronic response at concentrations of 77.5% and 42.4% effluent. Effluent from these outfalls produced statistically significant differences in hatchability at effluent concentrations of 100%. Only Inland Steel outfall 014 produced a statistically significant teratogenic response, affecting larvae in all dilutions tested. Within 168 hours of exposure, test organisms in effluent from E.I. DuPont de Nemours and Company (chemical industry) showed significant mortality in solutions with concentrations above 30% effluent. The DuPont effluent had a chronic value of 17.3% and statistically significant teratogenic responses were observed in concentrations above 30%. Hatchability was unaffected in all preliminary tests except USX outfall 034.

CHANGES IN FISH COMMUNITY STRUCTURE AND FUNCTION IN THE GRAND CALUMET

The fish communities of the Grand Calumet River watershed reflect the degraded condition of the stream. The dominant species include carp, goldfish and golden shiner. Pumpkinseed, central mudminnow, bluntnose minnow, chinook salmon and rainbow trout have also been collected (Simon et al. 1989). Because differential management strategies may need to be employed to restore the Grand Calumet River watershed, the watershed has been separated into four segments: 1) East Branch Grand Calumet River; 2) West Branch Grand Calumet River; 3) Indiana Harbor Canal, turning basin and outer breakwater; and 4) Grand Calumet Lagoons.

Fish communities of the Indiana Harbor Canal: Studies of the Indiana Harbor Canal were completed by Polls & Dennison (1984), Simon et al. (1989) and Risatti & Ross (1989). In addition, the U.S. Army Corps of Engineers, which is responsible for maintaining the Federal Channel of the Indiana Harbor Channel, conducted studies of the Federal Channel and outer breakwalls. Simon et al. (1989) assessed variation in fish community diversity of the Indiana Harbor Channel at Dickey Road bridge during 1986–1988. Risatti & Ross (1989) evaluated the turning basin and the outer harbor as part of a biological, toxicological and chemical evaluation for the U.S. Army Corps of Engineers.

Polls & Dennison (1984) sampled the Federal Channel in 1983 to quantify the concentration of contaminants in sediment and fish tissue. The information was used to assess the risk of removing sediments to maintain sufficient harbor depth for deep draft navigation. The canal entrance had the greatest biological diversity (11 species) and the lowest proportion of contaminant-tolerant taxa among the six stations surveyed (12.1%) (Table 3). The lowest percentage of non-native species was found in the Grand Calumet River branch (15.0%). Non-native species in this reach included alewife, carp, goldfish, carp-goldfish hybrids and brown trout (Table 3). The harbor was dominated by omnivores and detritivores such as carp, goldfish, bluntnose minnow, fathead minnow, central mudminnow and golden shiner, which represent a diverse group of fishes able to use the detrital forage base. Since 1994, the U.S. Army Corps of Engineers assessment has been restricted to electrofishing along the outer breakwaters at the Indiana Harbor entrance.

Simon et al. (1989) evaluated a single site for three years at Dickey Road bridge between 1986–1988. The unstable habitat conditions at the site prevented a stable fish community from colonizing. The number of species ranged from 2–14. Contaminant-tolerant species comprised 57.1–88.5% of the total community. The lowest percentage of tolerant species was observed during the 1988 drought when only two species were collected. The highest percentage of tolerant species was observed during 1987 when lower Lake Michigan levels enabled transient species to use the Harbor.

Risatti & Ross (1989) evaluated seasonal fish use at two locations. One site was near the anchor and turning basin; the second site included the entire channel between the Grand Calumet River Forks and the entrance to the canal (Table 3). Fewer species were collected in the anchor and turning basin than in the canal. Tolerant species comprised only 13% of the community composition at the anchor and turning basin site; tolerant species comprised over 57% of the population in the Forks to Canal reach. As in the 1984 study, Risatti and Ross found the lowest percentage of exotic species in the Canal. The outer breakwaters of the Indiana Harbor Canal have been monitored by the U.S. Army Corps of Engineers since 1994 (P. Moy, unpubl. data). The number of both species and individuals collected has increased between 1994–1996 (Table 3). This increase is attributed to greater numbers of tolerant (e.g., bluntnose minnow, fathead minnow, goldfish) and non-native (e.g., three spine stickleback and round goby) species that have colonized the area. Some contaminant-intolerant species have recently been collected including rock bass, black crappie and mottled sculpin. Unfortunately, the increased number of tolerant species has surpassed the increased numbers of intolerant taxa. The benthic habitat has apparently improved during this time, enabling species such as silver and golden redhorse, mottled sculpin and round goby to colonize. It is uncertain whether these species will be permanent residents or whether they are only transient, opportunistic species.

Fish communities of the East Branch of the Grand Calumet: Fish communities of the East Branch of the Grand Calumet River have been monitored since 1976. The East Branch was studied by CDM/Limnetic (1976), Indiana Department of Environmental Management (unpubl. data), Simon et al. (1989), Simon (1991) and Sobiech et al. (1994). The fish community of the East Branch has shown the greatest improvement of the four major reaches discussed in this paper.

CDM/Limnetics (1976) evaluated the confluence of the Grand Calumet River and the Indiana Harbor Canal during 1976. They collected only a single alewife from two sampling locations.

The Indiana Department of Environmental Management evaluated three locations in the East Branch since 1980. Fish are collected until the target number has been reached for fish tissue contaminant analyses (J. Stahl pers. comm.). During sampling, other non-target species are collected and enumerated. The 1980–1987 results show an increase in the number of species, a reduction in the percentage of tolerant species and an increase in river use by migrating transient species, including young-of-the-year yellow perch and adult rainbow trout.

Simon et al. (1989) evaluated seven locations on the East Branch between 1985–1988. The number of species increased at stations sampled multiple times. Generally, the dominant species in the East Branch fish community were carp, goldfish and golden shiner. Collections of pumpkinseed, largemouth bass, black crappie, bluegill, central mudminnow and rainbow smelt increased between 1985–1988 (Table 4). The lack of adult representatives of most species indicates that the area served as a nursery habitat and an intermittent food and habitat resource.

Simon (1991) developed biological integrity expectations for northwest Indiana as part of an evaluation of the Central Corn Belt Plain. An index of biotic integrity was developed and calibrated for the Lake Michigan subdivision of the Lake Michigan drainage. Three stations in the East Branch were sampled as part of this investigation. Although species lists were not reported by station, individual index of biotic integrity assessments were calculated for each station. The results did not differ significantly from the 1988 results (Simon et al. 1989). The 1990 survey was a high-water year, so many species that were not collected during the 1988 drought, including pumpkinseed and yellow perch, were found as they began returning to the area. An increase in the abundance of the rudd (*Scardinius erythrophthalmus*), a European non-native minnow, was noted in the East and West Branches of the Grand Calumet River. Non-native species make up the majority of the fish species collected (Table 3).

In 1988, there was a fish kill in the upper five miles (9 km) of the East Branch of the Grand Calumet River due to an upper river oil spill, which degraded water quality. Fish kills provide an opportunity to assess fish abundance and community composition. Significant numbers of alewife, carp and goldfish were reported from this fish kill. Notably, additional species, including northern pike, walleye and bluntnose minnow, were also killed. Sobiech et al. (1994) evaluated the upper five miles (9 km) of the East Branch of the Grand Calumet River as part of a pre-remediation assessment of the area. These authors did not find a resident fish community above Broadway, but a resident community composed of

Table 3.—A summary of the fish species collected from the Indiana Harbor Canal: A = harbor mouth breakwaters (IH4); B = anchor and maneuvering basin (IH4); C = canal entrance (IH4); D = canal section lakeward of the Forks (IHC3); E = the Lake George branch (IHC2); F = the Calumet River branch (IHC1); and G = Indiana Harbor at the Dickey Road bridge (IHC3). ^{1} = Polls & Dennison (1984); ^{2} = Simon et al. (1989); ^{3} = Risatti & Ross (1989); ^{4} = U.S. Army Corps of Engineers (unpublished data).

	1983						1986	1987	1988			1994	1995	1996
Species	A^1	B^1	C^1	D^1	E^1	F^1	G^2	G^2	G^2	D, E, F^3	B^3	A^4	A^4	A^4
Gizzard shad (*Dorosoma cepedianum*)	41	8	705	47	3	72		65		25	14	13	3	4
Alewife (*Alosa pseudoharengus*)	6		74			1		4		2	25	23		14
Chinook salmon (*Oncorhynchus tschawytscha*)												1		2
Coho salmon (*Oncorhynchus kisutch*)								1						
Brown trout (*Salmo trutta*)	1												1	
Rainbow trout (*Oncorhynchus mykiss*)							10	1			1			
Carp (*Cyprinus carpio*)	20	63	20	16	1	7	28	16		6	3	25	44	81
Goldfish (*Carassius auratus*)	1		106	26	133	25	3	22	4	5				1
Carp × goldfish hybrid					3			1						
Spotfin shiner (*Cyprinella spiloptera*)								1						
Golden shiner (*Notemigous crysoleucas*)				1			1	12		24				
Emerald shiner (*Notropis atherinoides*)			20				5	2		1		2	1	3
Spottail shiner (*Notropis hudsonius*)			18									7	3	10
Bluntnose minnow (*Pimephales notatus*)			3					10				3		4
Fathead minnow (*Pimephales promelas*)			5	6		22		1					2	8
Silver redhorse (*Moxostoma anisurum*)												4	2	1
Golden redhorse (*Moxostoma erythurum*)													2	
Three-spine stickleback (*Gasterosteus aculeatus*)														8
Rock bass (*Ambloplites rupestris*)			1									1	1	2
Pumpkinseed (*Lepomis gibbosus*)	2	2	10	22	22	28	1	8	3			3	4	9
Bluegill (*Lepomis macrochirus*)				1				2						
Bluegill × pumpkinseed hybrid										3	3			
Green sunfish (*Lepomis cyanellus*)					1									
Smallmouth bass (*Micropterus dolomieu*)												1	5	16
Black crappie (*Pomoxis nigromaculatus*)														1
Yellow perch (*Perca flavescens*)	7	8	371	39	4	64	1	2						
Mottled sculpin (*Cottus bairdi*)														2
Round goby (*Neogobius melanostomus*)														1
Freshwater drum (*Aplodinotus grunniens*)												2	7	1

Table 3.—Continued.

Species	1983						1986	1987	1988			1994	1995	1996
	A[1]	B[1]	C[1]	D[1]	E[1]	F[1]	G[2]	G[2]	G[2]	D, E, F[3]	B[3]	A[4]	A[4]	A[4]
Total number	78	81	1333	158	167	220	49	148	7	66	45	85	75	168
Total species	7	5	11	10	7	8	7	14	2	6	3	11	14	19
Tolerant species (%)	29.5	79.3	12.1	46.9	95.7	37.7	63.3	88.5	57.1	57.6	13.0	47.1	78.9	73.2
Exotic species (%)	35.9	76.8	65.0	27.8	81.2	15.0	83.7	30.4	57.1	19.7	62.2	56.5	60.5	63.7

tolerant and exotic species was observed downstream of this area. The rudd was also collected in this reach and was hybridizing with the native golden shiner.

Fish communities of the West Branch of the Grand Calumet: Few studies have been conducted in the West Branch of the Grand Calumet River (Table 5). The West Branch is the most degraded section of the entire watershed. Poor dissolved oxygen conditions, contaminated sediments, frequent bypass events from a municipal discharger and combined sewer overflows have severely degraded habitat in this reach.

Simon et al. (1989) and Simon (unpubl. data) evaluated the fish community at several stations in the West Branch, including sites up- and downstream of Indianapolis Boulevard, Roxanna Marsh and the discharge canal of the East Chicago Sanitary District. Spacek (1996) provides an account of unsubstantiated reports of salmon spawning from the East Chicago Sanitary District.

Between 1985–1988, Simon et al. (1989) sampled fish at three stations including the area around Indianapolis Boulevard, east of the I-90 highway bridge to the eastern edge of Roxanna Marsh and east of Columbia Avenue to the western side of the I-90 bridge. Only four species were collected during this period. No fish were collected on several occasions in 1985 at the Columbia Avenue site and in 1988 at Indianapolis Boulevard. During the 1988 drought, the depth of the river declined to only a few inches. This prevented all but the smallest young-of-the-year fish from using the area. Dissolved oxygen concentrations were too low to support aquatic life. During 1985–1988, tolerant and exotic species comprised the majority of the fish collected.

The State of Indiana Department of Environmental Management has collected fish tissue samples from the West Branch at Indianapolis Boulevard since 1980 (J. Stahl pers. comm.). Their collections show that the West Branch fish community is dominated by exotic species including carp, goldfish and their hybrids. Water depth in the West Branch is influenced by Lake Michigan surface water levels. Often, as the surface of Lake Michigan drops, the reduced water depth in the West Branch prevents fish migration and may preclude use of the area by some fish species. The reduced water depth forces fish to remain

Table 4.—A summary of the fish collections completed in the East Branch of the Grand Calumet River: A = East Branch at its junction with the West Branch and the Indiana Harbor Canal (EB1); B = Kennedy Avenue (EB2); C = Cline Avenue (EB4/5); D = Bridge Street (EB8); E = East Broadway (EB13); F = adjacent to DuPont de Nemours (EB3); G = West Buchanan Street (EB11); H = Wabash Railroad (EB12); I = Wilson Street; J = I-90 ramp (EB10); K = West Broadway (EB14); and L = Tennessee Street (EB15). [1]= CDM/Limnetics; [2]= Indiana Department of Environmental Management, unpublished data; [3]= Simon et al. 1988; [4]= Sobiech et al. 1994.

	1976	1980	1982	1984	1985	1986	1987	1986	1987	1988	1994				
Species	A[1]	B, C, D[2]	B, C, D[2]	B, C, D[2]	B, C, E[2]	B, C, D[2]	B, C, D[2]	B, C, D[3]	B-G[3]	B, C, D[3]	H[4]	I[4]	J[4]	K[4]	L[4]
Gizzard shad (*Dorosoma cepedianum*)							96		157						
Alewife (*Alosa pseudoharengus*)	2						1		2	8					
Central mudminnow (*Umbra limi*)		1			3				16	1					
Chinook salmon (*Oncorhynchus tschawytscha*)								1							
Rainbow trout (*Oncorhynchus mykiss*)						11									
Carp (*Cyprinus carpio*)		5	18	5	31	111	19	59	165	36	1	4	3	13	
Goldfish (*Carassius auratus*)					34		113	157	140	161	6	128	10		
Carp × goldfish hybrid											1			13	
Rudd (*Scardinius erythrophthalmus*)											1	3	8	33	
Spotfin shiner (*Cyprinella spiloptera*)		1					1			12					
Golden shiner (*Notemigonus crysoleucas*)			1	10	124	64	25	222	140	239	61	53	53	15	
Golden shiner × rudd hybrid															1
Emerald shiner (*Notropis atherinoides*)							2			14					
Bluntnose minnow (*Pimephales notatus*)						92	21	1	5	3	2	9	14	16	2
Fathead minnow (*Pimephales promelas*)							1	1		1					
Black bullhead (*Ameiurus melas*)					1		1								

Table 4.—Continued

	1976	1980	1982	1984	1985	1986	1987	1986	1987	1988	1994				
Species	A[1]	B, C, D[2]	B, C, D[2]	B, C, D[2]	B, C, E[2]	B, C, D[2]	B, C, D[2]	B, C, D[3]	B-G[3]	B, C, D[3]	H[4]	I[4]	J[4]	K[4]	L[4]
White sucker (*Catostomus commersoni*)												1	2	1	
Rainbow smelt (*Osmerus mordax*)									1	1					
Pumpkinseed (*Lepomis gibbosus*)						48	14	59	41	1	2				
Bluegill (*Lepomis macrochirus*)							2	6	2	2					
Green sunfish (*Lepomis cyanellus*)					3			6			2	4	3		1
Largemouth bass (*Micropterus salmoides*)										2		1	2		
Black crappie (*Pomoxis nigromaculatus*)										1					
Yellow perch (*Perca flavescens*)		1				3	142		4			1		1	
Unidentified darter (Percidae)				1											
Total number	2	8	19	16	197	281	471	470	691	519	75	90	93	102	4
Total species	1	4	2	3	7	11	7	7	11	6	6	10	9	7	2
Tolerant species (%)	0.0	75.0	100.0	93.0	100.0	48.3	63.3	92.3	73.3	57.6	100.0	96.6	95.8	99.0	100.0
Exotic species (%)	100.0	0.0	94.7	31.3	33.0	28.1	83.7	45.0	22.2	19.7	12.2	21.3	20.0	68.0	0.0
Number of collections	2	3	3	3	3	3	3	6	11	61	1	1	1	1	1

Table 5.—A summary of the fish collected from sites in the West Branch of the Grand Calumet River: A = junction between the West Branch and the East Branch of the Grand Calumet River (WB1); B = Indianapolis Boulevard (WB3/including WB2); C = East I-90 to the east side of Roxanna Marsh (WB4); and West I-90 east to Columbia Avenue (WB5). ^{1} = Simon et al. 1988; ^{2} = Simon 1991; ^{3} = Simon unpublished data.

	1985		1986		1987		1988	1990		1994
Species	C	D^1	B^1	A^1	B^1	C^1	B^1	B^2	B^3	C^3
Gizzard shad (*Dorosoma cepedianum*)					3					
Carp (*Cyprinus carpio*)	2		20	21	17			6	18	10
Goldfish (*Carassius auratus*)	12		22			1		2	9	5
Carp × goldfish hybrid								1		
Golden shiner (*Notemigonus crysoleucas*)				1	1		9	7		
Rudd (*Scardinius erythrophthalmus*)							1	10	1	
Bluntnose minnow (*Pimephales notatus*)								90		
Fathead minnow (*Pimephales promelas*)								1		
Black bullhead (*Ameiurus melas*)								1		
Green sunfish (*Lepomis cyanellus*)								2	1	
Pumpkinseed (*Lepomis gibbosus*)								1		
Total number	14	0	42	22	21	1	0	112	47	16
Total species	2	0	2	2	3	1	0	7	6	3
Tolerant species (%)	100.0	0	100.0	100.0	85.7	100.0	0	100.0	97.8	100.0
Exotic species (%)	100.0	0	100.0	95.4	80.9	100.0	0	8.0	80.9	100.0
Number of collections	2	0	2	1	3	1	2	1	1	1

close to the contaminated sediment characteristic of the area.

In 1990, most of northwestern Indiana was affected by significant flooding. The surface elevation of Lake Michigan and the depth of the West Branch increased. Samples from the Indianapolis Boulevard area included the greatest number of fish from the West Branch: seven species (Simon 1991). The first West Branch collection of the eurasian rudd (*Scardinius erythrophthalmus*) was included with this catch. The water quality of the discharge canal at East Chicago Sanitary District enabled several very tolerant species, such as green sunfish and bluntnose minnow, to inhabit the West Branch. The fish community downstream of Indianapolis Boulevard was numerically dominated by carp and goldfish; however, the percentage of exotic species was significantly reduced and native species, such as bluntnose minnow and green sunfish, increased (Table 5). Fish at this site had high percentages (4.5%) of deformities, eroded fins, lesions and tumor (DELT) anomalies; fish were collected that had eroded fins, fungus, and lesions.

Simon (unpubl. data) sampled the West Branch in the vicinity of Indianapolis Boulevard and Roxanna Marsh during 1994. One site extended from the east side of Indianapolis Boulevard to an area approximately 50 m upstream from the junction of the East and West Branches. The East Chicago Sanitary District discharge canal was included in this sampling site. The second location included the area from Indianapolis Boulevard west along the edge of Roxanna Marsh to the I-90 bridge. The fish community of the West Branch exhibited some improvement since sampling began in 1985; however, it still does not have the same biological integrity as the East Branch. Significant loss of community function has occurred in the West Branch; and as of 1994, many of the resident fish are tolerant, exotic detritivores. These taxa with flexible forage habits are often the first to occupy an area when pollution impacts and water quantity limitations are reduced and environmental conditions begin to improve. The fish community west of Indianapolis Boulevard, including Roxanna Marsh, has remained similar since monitoring began in 1985 (Simon et al. 1989).

Dominance by pollution-tolerant carp and goldfish and the absence of native species indicate extreme degradation. During the drought of 1988, even tolerant species were unable to inhabit the West Branch because of low water depths and poor dissolved oxygen conditions. Recolonization by carp and goldfish created a species composition similar to that observed in 1985. The presence of carp and goldfish hybrids shows disruption of reproductive strategies and is considered a reduction in biological integrity. The presence of high proportions of DELT anomalies also suggests that biological integrity is declining.

One reason that water quality in the Grand Calumet River is improving might be the presence of chinook salmon adults and fingerlings in the East Chicago Sanitary District's contact disinfection chamber. Spacek (1996) reported that chinook salmon were able to spawn in the district's contact disinfection chamber because of "well-oxygenated, high quality effluent water." Spacek (1996) suggested that this evidence is the first of Pacific salmon spawning in southern Lake Michigan. The problems with the documented evidence are substantial, and these problems make it difficult to conclude that the water quality of the West Branch of the Grand Calumet River has improved.

Grand Calumet Lagoons: Simon et al. (1989), Stewart & Simon (1995) and Simon & Stewart (1998) investigated the Grand Calumet Lagoon beginning in 1986. The State of Indiana Department of Environmental Management has collected fish from this area for tissue contaminant analyses. Simon & Stewart (1998) investigated the Middle and Western Lagoons during 1994–1995 to determine the status of the fish community as part of a larger study. The two lagoons are located east of the U.S. Steel site, and they are part of the Indiana Dunes National Lakeshore. The Lagoons are connected by a small stream, which usually drains to the west. Two small ponds, which were once backwaters or bays of the Grand Calumet Lagoons, are separated from the larger lagoons and are referred to as the West and East Ponds.

Shelford (1937) reported 20 species from the Grand Calumet Lagoons. Species collected during this period (Meek & Hildebrand 1910) reflect the least-impacted condition of the Grand Calumet since the flow of the river had only recently been reversed due to construction of the Indiana Harbor Canal.

The Indiana Department of Natural Resources (IDNR) has managed the recreational fishery in the East Lagoon since the mid-1960s. The lagoon is heavily fished, and over 60% of the shoreline is developed. The east end of the Lagoon is surrounded by homes, and a storm sewer empties into the East Lagoon near a pavilion. The IDNR collected channel catfish, bluegill, yellow perch, black crappie, largemouth bass, golden shiner, carp, lake chubsucker and goldfish from the East Lagoon (Robertson 1986). Largemouth bass, bluegill and black crappie were stocked in the East Lagoon in 1965. Channel catfish were stocked in 1982 and regularly between 1984–1992.

The western portion of the East Lagoon was treated with rotenone in 1966 to remove "rough fish" (e.g., carp and suckers). Robertson (1986) reported that after the rotenone treatment, bluegill abundance increased from 17.6–38.4%, though few were of catchable size. In 1973, 646 fish, including golden shiner (45.7%), bluegill (17%) and lake chubsucker (11.4%), were collected in the western portion of the East Lagoon. Largemouth bass, bluegill, black crappie and yellow perch comprised 30% of the sample. Robertson (1986) reported rosyface shiners in the East Lagoon, but these fish were probably misidentified emerald shiners.

Simon & Stewart (1998) studied the structure and function of the fish community of the Grand Calumet Lagoons. In many respects, the fish community of the Middle Lagoon resembles that reported for the Grand Calumet River basin by Meek and Hildebrand at the turn of the century (Table 1). Species such as lake chubsucker, Iowa darter, warmouth and pumpkinseed are found in the Middle Lagoon; centrarchids dominate the community (Table 6).

The array of subdominant fish species in the Middle Lagoon differs substantially from that in the West Lagoon. Species such as goldfish and bluntnose minnow are present in the West Lagoon; but warmouth, central mudminnow and lake chubsucker are found in the Middle Lagoon. Pumpkinseed are present in both the East and West Ponds; however, grass pickerel are present only in the East Pond. Exotic and tolerant species comprise a very low proportion of the fish community in the Middle Lagoon and both ponds. Stewart & Simon (1995) found Iowa darter (*Etheostoma exile*) in the East Lagoon. The species had previously been found in eastern Illinois and in Wolf Lake, but this report was the first record of this species in northwestern Indiana. The Wolf Lake population was thought by Smith (1979) to be extirpated; however, recent surveys have found them to be persistent (Simon unpubl. data).

Stewart & Simon (1995) and Simon & Stewart (1998) reported that the fish community of the West Lagoon is comprised of a greater percentage of tolerant species. This is probably a reflection of a more disturbed habitat, which provides a competitive edge for opportunistic, tolerant, detritivores such as carp, goldfish and bluntnose minnows.

BIOLOGICAL INTEGRITY

The biological integrity scores for fish communities of the Grand Calumet watershed indicated that the communities had "poor" to "very poor" integrity. Simon (1991) developed expected indices of biological integrity for fish communities in northwestern Indiana and the Central Corn Belt Plain Ecoregion. The Lake Michigan subdivision of the Lake Michigan Division shows declining water resource integrity with increasing drainage order for the entire Lake Michigan drainage. The Grand Calumet River achieved scores of poor (27.1%), poor-very poor (43.8%), very poor (20.8%) and no fish (8.3%); the West Branch had the lowest biological integrity. Simon et al. (1989) sampled a minimum of 2–3 times per year for four years to determine if biological integrity changed substantially at any of the twelve stations sampled. Of the nine stations that were sampled, the average index of biotic integrity score differed by less than 5 integrity points (range: 0–10 integrity points).

Other assessment categories were used at stations without fish. At these stations, the index of biotic integrity scores differed by more than 10 points. An Ohio study found that the largest departures in IBI scores were due to large scale disturbance (Yoder & Rankin 1995). In the Grand Calumet River, the wider fluctuations in IBI points also reflected highly disturbed conditions. The largest difference in IBI, within a single year, was 6 points at the

Table 6.—A summary of fish community structure and function found in the Grand Calumet Lagoons: A = dunal ponds identified by Shelford and assumed to be the Grand Calumet Lagoons; B = Middle Lagoon; C = West Lagoon; D = East Lagoon; E = West Pond; and ● = Presence data). [1] = Shelford 1937; [2] = Robertson 1986; [3] = Simon *et al.* 1988; [4] = Stewart & Simon 1995, and Simon & Stewart unpublished data.

	1909	1909	1986	1986	1995			
Species	A[1]	B[1]	D[2]	B[3]	B[4]	C[4]	D[4]	E[4]
Bowfin (*Amia calva*)	●							
Central mudminnow (*Umbra limi*)	●				1			
Grass pickerel (*Esox americanus*)	●	●			6		●	
Northern pike (*Esox lucius*)	●							
Carp (*Cyprinus carpio*)		●	●	18	2	17		
Goldfish (*Carassius auratus*)	●		●		1			
Carp × goldfish hybrid								
Common shiner (*Luxilus cornutus*)	●							
Golden shiner (*Notemigonus crysoleucas*)	●	●	●			2		
Emerald shiner (*Notropis atherinoides*)		●	●?					
Blackchin shiner (*Notropis heterolepis*)	●					51		
Bluntnose minnow (*Pimephales notatus*)								
Lake chubsucker (*Erimyzon sucetta*)	●	●	●	1	13			
Black redhorse (*Moxostoma duquesnei*)	●							
Black bullhead (*Ameiurus melas*)	●			1				
Yellow bullhead (*Ameiurus natalis*)	●	●			1			
Brown bullhead (*Ameiurus nebulosus*)	●							
Channel catfish (*Ictalurus punctatus*)			●					
Tadpole madtom (*Noturus gyrinus*)	●				1			
Green sunfish (*Lepomis cyanellus*)	●	●		2	12	15		
Pumpkinseed (*Lepomis gibbosus*)	●	●		1	70	32	●	●
Warmouth (*Lepomis gulosus*)	●	●			20	2		
Bluegill (*Lepomis macrochirus*)	●	●	●	5	113	27		
Largemouth bass (*Micropterus salmoides*)	●	●	●	2	26	94		
White crappie (*Pomoxis annularis*)		●						
Black crappie (*Pomoxis nigromaculatus*)		●	●	1	1			
Yellow perch (*Perca flavescens*)	●	●	●		9	25		
Iowa darter (*Etheostoma exile*)				8	4			
Total number	—	—	—	30	297	281	—	—
Total species	20	14	10	7	14	11	1	1
Tolerant species (%)	30.0	30.0	30.0	70.0	5.4	30.6	0.0	0.0
Exotic species (%)	0.0	14.3	20	60	0.1	6.4	0.0	0.0
Number of collections	—	—	1	1	3	3	2	2

site to the east of Indianapolis Boulevard in 1987 (Table 7).

FISH CONSUMPTION ADVISORIES

The Indiana State Department of Health (ISDH) (1997) found that fish from the Grand Calumet River should not be consumed, primarily due to contamination by PCBs and mercury. Table 8 lists the fish species and sizes (total length in cm) included in the consumption advisory. The advisory is less restrictive for the Marquette Park Lagoon, recommending only that largemouth bass more than 30 cm long be avoided. A statewide advisory exists on carp consumption: 1 meal/month of carp 37.5–50 cm long, 1 meal/2 months for carp 50–62.5 cm long and no carp over 62.5 cm should be consumed.

Numerous species in the nearshore of Lake Michigan also are restricted for consumption. Factors that would limit complete removal of consumption advisories and eventual recovery and delisting of the Grand Calumet River are: 1) Lake Michigan species that enter the river during migration include wide-ranging salmonids; 2) resident species in the Grand Calumet River would require several generations to reduce body burdens; and 3) stocking of

Table 7.—The index of biotic integrity values for the Grand Calumet watershed from 1985 to 1990 (Simon et al. 1988; Simon 1991). The sites indicated below are: 1 = West Lagoon; 2 = East Branch Grand Calumet River at Broadway (EB13); 3 = East Branch Grand Calumet River at Bridge Street (EB8); 4 = East Branch Grand Calumet River at East Buchanan Street (EB10); 5 = East Branch Grand Calumet River at Cline Avenue (EB4); 6 = East Branch Grand Calumet River at Kennedy Avenue (EB2); 7 = East Branch Grand Calumet River at the DuPont de Nemours outfall (EB4); 8 = Junction of the East and West Branches of the Grand Calumet River (EB1/WB1); 9 = West Branch Grand Calumet River at Indianapolis Boulevard (WB3); 10 = West Branch Grand Calumet River at the I-90 bridge (WB4); 11 = West Branch Grand Calumet River at Columbia Avenue (WB5); and 12 = Indiana Harbor Canal at Dickey Road (IHC3).

		Sites											
Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1985	October			24			24		24			24	0
1986	June	32		26		24	24			22			24
	October			28		30	28			20			26
1987	April		30	32	24	22		22	22	24	24		
	April			24		24	26			22			28
	November			32		30	30			0			34
1988	May			26		22	24			0			
	July			28		32	26			0			24
1990	July			24		20	32			21			16
Index of Biotic integrity													
Average		32	27	27.5	24	25.3	27.1	23	22	13.6	24	0	25.3
Minimum		32	24	24	24	20	24	22	22	0	24	0	16
Maximum		32	30	32	24	32	32	24	22	24	24	0	34
Standard deviation		—	3	1.0	—	1.33	1.14	1.0	—	3.0	0	—	3.0
Number of collections		1	2	8	1	9	7	2	1	8	2	1	6

Table 8.—Fish consumption advisories issued for the study area.

	Species	Length (cm.)	Concern	Meals/ month
Lake Michigan	Black crappie	17.5–20.0	PCB's	1
		20+	PCB's	0.5
	Brook trout	All	PCB's	1
	Brown trout	<45	PCB's	1
		45–67.5	PCB's	0.5
		67.5+	PCB's	0
	Carp	All	PCB's, mercury	0
	Catfish	All	PCB's	0
	Chinook salmon	<65	PCB's	1
		65+	PCB's	0.5
	Coho salmon	42.5–70	PCB's	1
		70+	PCB's	0.5
	Goldfish	10+	PCB's	0
	Golden shiner	7.5–15	PCB's	0
	Lake trout	<52.5	PCB's	1
		52.5–65	PCB's	0.5
		65+	PCB's	0
	Largemouth bass	10–17.5	PCB's	1
		17.5+	PCB's	0.5
	Longnose sucker	35–57.5	PCB's, mercury	0.5
		57.5+	PCB's	0
	Northern pike	25–35	PCB's	1
		35+	PCB's	0.5
	Pink salmon	All	PCB's	1
	Rainbow trout	<55	PCB's	1
		55+	PCB's	0.5
	Walleye	42.5–65	PCB's	1
		65+	PCB's	0.5
	Whitefish	<57.5	PCB's	1
		57.5+	PCB's	0.5
	White sucker	37.5–57.5	PCB's, mercury	1
		57.5+	PCB's	0.5
Grand Calumet River and the Indiana Harbor Canal	All species	All	PCB's, mercury	0

non-indigenous species and migration of species from other more contaminated areas into the river will require more time to see decline in contaminant body burdens. Recovery and restoration objectives for fish communities in the Grand Calumet River could initially strive to reach the same contaminant levels as Lake Michigan fish.

Fish bioaccumulation, body burdens and contaminant levels: Steffek (1989) evaluated three abandoned hazardous waste dumps in the Grand Calumet River watershed. Steffek collected a variety of organisms representing various trophic levels and feeding regimes. Earthworms, turtles, crayfish, fish and small mammals were tested for body burdens. Compounds found at elevated levels in whole body tissue samples included acetone, 2-butanone, benzene, trichloroethane, toluene, ethylbenzene, total xylenes, aluminum, copper, chromium, lead, manganese and silver. Values for lead were above the national levels obtained from the national biomonitoring program (Lowe et al. 1985). Taxa collected as environmental indicators showed various effects. Earthworms were absent from many of the sites but showed mixed results due to illegal dumping and mixed contamination. Fish, mudpuppy and crayfish provided important bioaccumulation information for inorganic and volatile compounds, while turtles did not show significant results.

Sparks & Hudak (1996) reviewed available information on environmental impacts associated with the dredging of the Indiana Harbor Canal. High sediment levels of polycyclic aromatic hydrocarbons (PAHs), phenols, cyanide, metals and ammonia have been detected in the Harbor sediments. Although bullhead species are not common in this study area, Baumann et al. (1987), Baumann (1989) and Baumann et al. (1991) have documented a stressor-response effect between PAH-contaminated sediments and incidence of liver neoplasia in brown bullheads. Levels of PAHs detected in the sediments of the Indiana Harbor Canal would be sufficient to cause elevated incidences of hepatic neoplasias.

SUMMARY AND RESTORATION POSSIBILITIES

Construction of Indiana Harbor, development and changes in land use, and expansion of heavy industry along the Grand Calumet River have severely degraded the fish habitat. This degradation was evident by the low catch rates and minimal diversity of the fish community during the mid 1970s. Improvements in water quality through the later 1970s and into the 1980s allowed for significant improvements in the Grand Calumet River fish community; however, current biotic integrity indices still characterize the community as "very poor."

Two pieces of evidence suggest that improvement and maintenance of water quality will be an essential factor in the recovery of the aquatic community. First, Simon et al. (1989) observed that the fish community rebounded during the USX shutdown. This could only have been a result of improved water quality because no sediment remediation took place. Second, the presence of salmonids in both the East Chicago and Gary sewage treatment plant discharges suggests that improvements in the quality of the discharge water have been sufficient to attract these fish on their spawning migrations. Departures in water quality standards and violations of NPDES permits still occasionally occur, and they are sufficient to cause mortality of young salmonids and other species.

Removal of contaminated sediment from the Grand Calumet River would likely improve the benthic macroinvertebrate community, which supplies forage for bottom-feeding fishes such as native suckers; and it would also reduce the potential for bioaccumulation from contaminated sediment. However, without sufficient water quality, the fish community is unlikely to recover beyond its present degraded condition. A combination of low dissolved oxygen, relatively high water temperatures, inadequate invertebrate forage and lack of heterogenous substrates result in low habitat diversity and suppressed community diversity.

Dredging/sediment clean-up impacts: Flow velocity in the Grand Calumet River varies with effluent discharge volumes (Crawford & Wangsness 1987). Channel depth through the length of the study area is highly variable, ranging from 8–10 feet (~ 3 m) in the Grand Calumet Lagoons to one foot (~ ⅓ m) or less in portions of the West Branch near the State Line. Removal or isolation of contaminated sediment and consequent reduction of sediment resuspension may improve water quality after sediment remediation is complete. Deepening the channel, however, will create a pool-like habitat with slower current and possibly reduce dissolved oxygen. The additional water depth may prohibit the re-establishment of rooted vegetation which provides substrate for invertebrates, cover for fish and an oxygen source.

The dredging and the sediment clean-up process may temporarily degrade water quality and reduce aqueous habitat quality. Dredging suspends sediment in the water column, which can increase turbidity and dissolved contaminant concentrations and reduce dissolved oxygen. These impacts tend to be temporary, and ambient levels return shortly after dredging ceases. Discharge from the dewatering site must be treated to reduce contaminant concentration and thereby meet state water quality standards. Care must be taken to assure that the discharge does not adversely affect instream dissolved oxygen and that toxic chemical concentrations, such as ammonia, are within acceptable limits. Weirs surrounding the dredge site can help contain water quality impacts within the immediate dredging area.

Long-term habitat impacts would result as dredging converts shallow littoral habitat to more pelagic habitat with steep banks and a narrow littoral zone. The vegetation in the littoral zone forms important foraging and nursery habitat for young fish. In order to re-establish this important aquatic habitat, water depths and clarity after dredging need to be created so that light can penetrate to the bottom.

Opportunities for improving aquatic habitat: In 1985, the USEPA identified two factors that reduced the quality of biological habitat in portions of the Grand Calumet River: slow-flowing or stagnant water in the West Branch warms quickly, causing decreased dissolved oxygen concentrations; and particulates settle over detrital matter and suffocate benthic organisms. The USEPA (1985) stated that these conditions are typical of many stream-mouth environments in the Great Lakes, but the conditions are exaggerated in the West Branch of the Grand Calumet River.

Flow reversals due to fluctuations in Lake Michigan water levels have less impact on the East Branch and main stem due to the high lakeward flow rate sustained by industrial effluent, particularly from USX. Without a high volume of industrial discharges, the majority of the Grand Calumet River would probably be less suitable for fish and aquatic life (assuming adequate control of pollutants in the effluent) (USEPA 1985).

An additional obstacle to restoration is the intensity of urban and industrial development within the watershed. Most precipitation falling to the basin is captured on non-porous surfaces, such as roof drains or parking lots and roadways, and is then diverted to the river via storm drains. This reduces the opportunity for soil filtration of dissolved and suspended pollutants, exaggerates peak flows, depresses low flows, reduces dilution of groundwater contaminants and slows dispersion from origin to discharge point along the river. Establishing aeration stations that use either injected air or elevated sidestream aerators could help to improve the aquatic habitat by maintaining adequate dissolved oxygen concentrations and by assisting in the breakdown of organic debris.

After the contaminated sediment is removed, the remaining channel profile needs a littoral zone. The rooted vegetation that grows in the littoral zone provides forage and cover for invertebrates and young fish, as well as ambush sites for predatory species. Creating a littoral zone could involve replacing dredged material with clean material in some portions of the river. Replacement with gravel or other substrate would provide substrate heterogeneity suitable for lithophilic spawners and nest builders such as suckers, darters and sunfish; and it may facilitate the re-establishment and maintenance of these populations. Woody debris, such as brush piles, stumps or logs placed along the channel border, can form current breaks, nesting cavities, hard surfaces for the attachment of adhesive eggs and habitat for invertebrates. Half-logs can be placed in the center of the channel to provide cover and shaded areas for species that previously would have used aquatic vegetation. Wetland, bog and dune areas adjacent to the river may serve as spawning and rearing areas for many important fish species (USEPA 1985). Creation of artificial wetlands and shallow side channels would form more of this important limiting habitat.

Innovative dredging techniques could be used to create side channels through the heavily choked *Typha*, *Phragmites* and purple loosestrife stands adjacent to the river. These side channels could be staggered and parallel to the channel to emulate a braided wetland channel. The entrance to these areas could be kept open by installing deflector logs to scour and divert flow from the main channel. In addition, many depth profiles could be established by refilling with clean sand. Also, side-channel wetlands could be created by dredging perpendicular to the channel and then filling with clean sand to create a shelf zone. This area could be planted with native emergent wetland plants which would serve as fish nursery habitat and as foraging and resting areas for wading birds, reptiles and mammals. A rigorous effort to control exotic, invasive plant species would have to be implemented to control reinvasion of exotic plant species after initial efforts are implemented.

After sediment clean-up, the water quality of industrial and municipal discharges will need to meet NPDES permit requirements. Further treatment and design improvements are needed to reduce impacts attributable to thermal pollution, nutrient enrichment, combined sewer overflows and other non-point source influences. A single episode of oxygen depletion could eliminate an entire year class of young fish. Without continued emphasis on meeting designated uses and NPDES permit limits, little or no improvement of the fish community can be expected.

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For much of its length, the Grand Calumet River runs alongside the I-90 toll road. Steep banks can increase runoff into the river and eliminate natural wetland areas along the river's banks.

There are numerous outfalls that flow directly into the river from industry and sanitary systems. Much of the outfall is cooling water or sanitized water, but nonetheless it greatly alters the chemistry of the river and impacts the biological communities. The Grand Calumet River runs through a highly populated region and therefore experiences excessive impacts associated with municipalities and industry.

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AMPHIBIANS AND REPTILES OF THE GRAND CALUMET RIVER BASIN

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ABSTRACT. The Grand Calumet River and its associated dune and swale areas of northwest Indiana is a globally unique ecosystem. However, it has been nearly obliterated by industrial, commercial, and residential development. Remnant natural areas, some protected, some not, harbor an incredibly diverse array of amphibians and reptiles. This area features species whose ranges converge from all four compass directions, hence generating the impressive diversity. Clean up of the Grand Calumet River and improvement of riparian areas should help maintain this diversity. In addition, preservation of unprotected sites and well-planned habitat linkages will further enhance preservation of this diversity for generations to come.

Keywords: Grand Calumet River, Indiana, amphibians, reptiles, habitat quality, habitat protection, dune and swale

The ridge and swale area (Fig. 1) surrounding the Grand Calumet River is home to one of the more diverse assemblages of amphibians and reptiles in northwest Indiana. Each time Lake Michigan receded, a dune ridge formed trapping an elongate wetland behind it. Well over 100 ridges originally existed in what is now Gary, East Chicago, and Hammond, Indiana. Here, as a result of recent geologic and climatic events, species more typical of areas to the north, south, east, and west come together and occur in close proximity. Surprisingly, despite the long and intensive industrial history of the region, several relatively pristine natural areas have survived along with most of their salamander, frog, turtle, lizard, and snake species. The survival of these natural areas and their associated faunas provides unique opportunities for preservation and restoration.

In addition to the immediate riparian area, the contiguous ridge and swale sites were included in the study. Since amphibians and reptiles are less mobile than many other vertebrates and less likely to colonize remote or isolated habitats, existing centers of biodiversity must be inventoried, and the data factored into management decisions. Information available from recent inventories and older museum specimens and publications supplemented our own field experience in the area. Nomenclature follows Collins (1990), except the for the more recent elevation of *Bufo fowleri* to specific status (Sullivan et al. 1996).

PRE-SETTLEMENT CONDITIONS

Origin of the herpetofaunal assemblage.—Presumably, amphibians and reptiles entered what is now the Grand Calumet River area shortly after the end of the Wisconsinan glaciation. Remains of the cold-tolerant turtles, *Chelydra serpentina* and *Chrysemys picta*, have been found in association with mastodon bones in southeastern Michigan and east-central Indiana (Holman & Andrews 1994) at sites dated to 13,000–11,000 years before present (ybp). Other species that today have northern distributions also must have been present in the boreal forest that covered northwest Indiana at that time. However, the present-day site of the Grand Calumet River was still covered by the waters of post-glacial Lake Chicago. Subsequent fluctuation of lake levels (Chrzastowski & Thompson 1992; Chrzastowski et al. 1991) and climate change (Ahearn & Kapp 1984; Ebbers 1984) profoundly influenced the sequence and location of later colonization events.

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The diverse herpetofauna includes northern elements (e.g., the blue-spotted salamander, *Ambystoma laterale*, and Blanding's turtle, *Emydoidea blandingii*) and eastern species (e.g., the eastern newt, *Notophthalmus viridescens*, and the green frog, *Rana clamitans*). These species may have been present since not long after glacial retreat, and they persist today in moist woodland and wetland habitats. Species of western or southern origin and characteristic of warmer or drier conditions (e.g., Fowler's toad, *Bufo fowleri*, the six-lined racerunner, *Cnemidophorus sexlineatus*, and the western slender glass lizard, *Ophisaurus attenuatus*) presumably entered the Calumet region during a hypsithermal interval (Smith & Minton 1957) about 6200 to 5050 ybp (Ahearn & Kapp 1984). Today, these species inhabit xeric dunes or open grasslands.

The parallel sand ridges north of the Grand Calumet River did not form until about 2500–1000 ybp (Thompson 1992). This landscape is very young, even for our recently glaciated region. Amphibian and reptile populations inhabiting dune and swale habitat must have colonized new wetlands and ridges as they formed.

In the 1830's, the Grand Calumet River was a shallow, sluggish body of water bordered by emergent marshes. Nearby upland ridges were usually open sand savanna interspersed with areas of dry-mesic to wet sand prairie. Adjacent swales also were diverse, with open water, marsh, and shrub swamp communities. Because of the diversity of available habitat and the unusual history of the areas, a unique assemblage of amphibians and reptiles was present at the time of settlement.

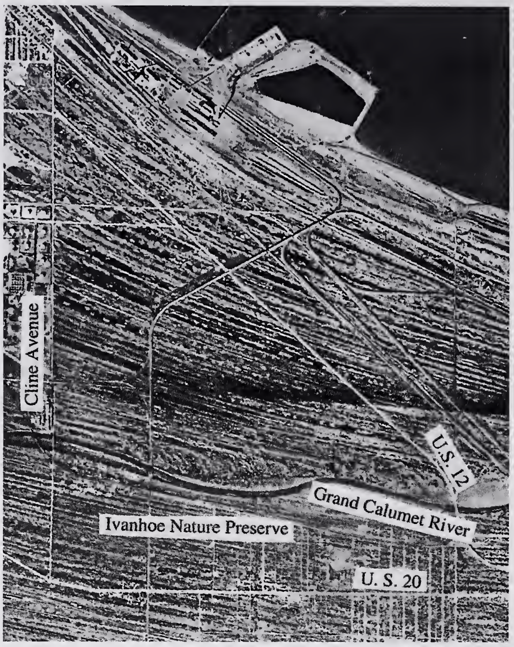

Figure 1.—A 1939 aerial photo of a section of the Grand Calumet River in west Gary and east Hammond (westernmost north-south road is Cline Avenue, the border between the two cities). The numerous rows of dune and swale are evident. U.S. 20 is the southernmost east-west roadway, and U.S. 12 angles from the southeast corner of the photo to the northwest corner. The Grand Calumet River (dark curved line) snakes through the bottom third of the photo. Ivanhoe Nature Preserve is the second and third "blocks" of swales northeast from the intersection of Cline Avenue and U.S. 20. The "hooked" dune ridges to the north of the Grand Calumet River mark successive mouths of the river as the mouth migrated eastward with the development of each new ridge. Photo and description courtesy of Steve Brown, Indiana Geological Survey.

Sources of information.—Any reconstruction of the pre-settlement herpetofauna must rely in part on somewhat later sources. The first museum specimens form the area were collected in 1902, but no records of amphibians or reptiles in the Grand Calumet River area were published prior to Shelford (1913), who listed species at a few localities west of Gary.

Combining early published sources, specimens in area museum collections, and knowledge based on the best remaining natural areas and examples of particular habitat types, a potential total of 34 species of pre-settlement amphibians and reptiles has been compiled (Table 1). The sluggish open-water channel of the Grand Calumet River must have been inhabited by a variety of fully aquatic species. Snapping turtles (*Chelydra s. serpentina*), musk turtles (*Sternotherus odoratus*), and painted turtles (*Chrysemys picta marginata*) were certainly present in the lagoons by Miller, now in northeast Gary, in the early part of this century, because they are documented by museum specimens. Shelford (1913) reported the three species listed above, as well as map turtles (*Graptemys geographica*), in ponds north of the river at Clark Street (Sites 11 and 12 in Fig. 2), and these species may have been present in the channel as well. Mudpuppies (*Necturus maculosus*) still occur in Wolf Lake (straddles the Indiana/Illinois state line in northwest Hammond) and in Lake Michigan; they may have entered the river before severe water degradation.

Table 1.—Potential amphibian and reptile species during presettlement times in the Grand Calumet River basin. All authors of species are as in Minton (2001).

Frogs and toads
- *Acris crepitans blanchardi* (Northern cricket frog)
- *Bufo americanus* (American toad)
- *Bufo fowleri* (Fowler's toad)
- *Hyla versicolor* (Gray tree frog)
- *Pseudacris crucifer crucifer* (Spring peeper)
- *Pseudacris triseriata triseriata* (Western chorus frog)
- *Rana catesbeiana* (Bullfrog)
- *Rana clamitans melanota* (Green frog)
- *Rana pipiens* (Northern leopard frog)

Salamanders
- *Ambystoma laterale* (Blue-spotted salamander)
- *Ambystoma tigrinum tigrinum* (Eastern tiger salamander)
- *Necturus maculosus* (Mudpuppy)
- *Notophthalmus viridescens* (Eastern red-spotted newt)
- *Plethodon cinereus* (Redback salamander)

Snakes
- *Coluber constrictor* (Blue racer)
- *Elaphe vulpina vulpina* (Western fox snake)
- *Heterodon platirhinos* (Eastern hognose snake)
- *Lampropeltis triangulum* (Milk snake)
- *Nerodia sipedon* (Common water snake)
- *Opheodrys vernalis* (Smooth green snake)
- *Regina septemvittata* (Queen snake)
- *Storeria dekayi wrightorum* (Midland brown snake)
- *Thamnophis proximus proximus* (Western ribbon snake)
- *Thamnophis radix radix* (Plains garter snake)
- *Thamnophis sirtalis sirtalis* (Eastern garter snake)

Turtles
- *Chelydra serpentina serpentina* (Common snapping turtle)
- *Clrysemys picta marginata* (Midland painted turtle)
- *Clemmys guttata* (Spotted turtle)
- *Emydoidea blandingii* (Blanding's turtle)
- *Graptemys geographica* (Common map turtle)
- *Sternotherus odoratus* (Common musk turtle)

Lizards
- *Cnemidophorus sexlineatus* (Six-lined racerunner)
- *Eumeces fasciatus* (Five-lined skink)
- *Ophisaurus attenuatus attenuatus* (Western slender glass lizard)

Riparian wetlands probably provided foraging areas for all of the above species, as well as semi-aquatic species such as bullfrogs (*Rana catesbeiana*), green frogs (*Rana clamitans melanota*), Blanding's turtles (*Emydoidea blandingii*), and common water snakes (*Nerodia sipedon*). Terrestrial species may have entered riparian areas on occasion, but did not permanently reside there.

Swales adjacent to the river provided habitat for a rich array of species. Salamanders and frogs used these wetlands for breeding, and several species of turtles and snakes probably reached maximum abundance there. Shelford (1913) listed tiger salamanders (*Ambystoma t. tigrinum*), red-spotted newts (*Notophthalmus viridescens*), northern leopard frogs (*Rana pipiens*), snapping turtles (*Chelydra s. serpentina*), musk turtles (*Sternotherus odoratus*), painted turtles (*Chrysemys picta marginata*), map turtles (*Graptemys geographica*), and garter snakes (*Thamnophis s. sirtalis*) from swales near Clark Street (Sites 11 and 12 in Fig. 2). Various terrestrial species occupied the intervening sand prairie and savanna.

CURRENT STATUS

Grand Calumet River channel.—Because of severe water quality degradation, only a few tolerant reptiles presently inhabit the

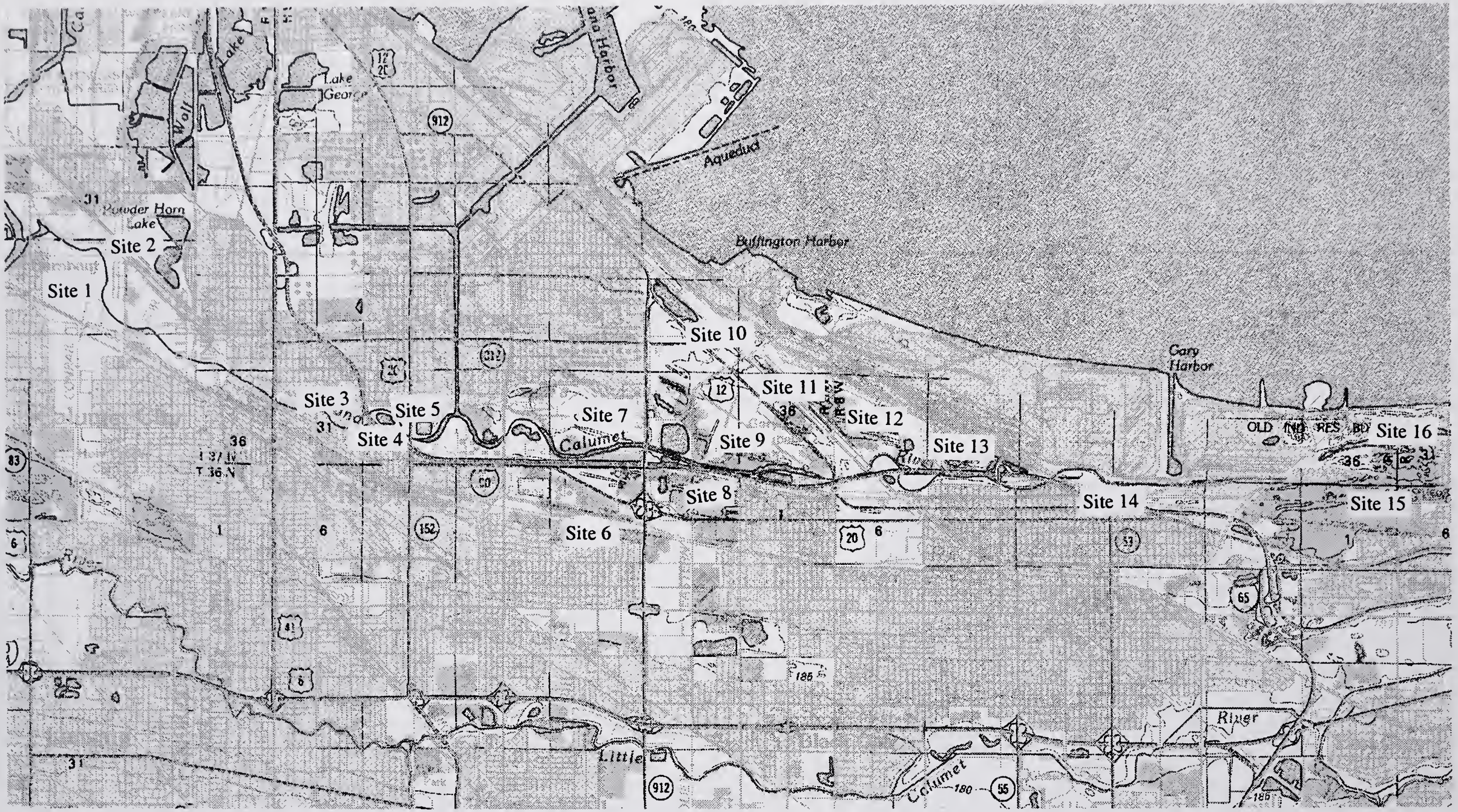

Figure 2.—Recent map of the Grand Calumet River, with the numbered sampling sites located along the north and south sides of the river. Each numbered reference site is named in the text.

channel of the Grand Calumet River. Snapping turtles and painted turtles have been reported from the eastern reaches of the river (Sobiech et al. 1994), and the authors observed both species at several locations from the Hammond Sanitary District (Site 3 in Fig. 2) to United States Steel Corporation (Site 14 in Fig. 2). Both species are relatively tolerant of poor water quality. At present, no amphibians are permanent residents of the open channel, although individual animals may enter the area from time to time.

Riparian areas.—Recent searches of riparian marshes have not revealed any amphibians or reptiles. Monospecific stands of common reed (*Phragmites australis*), which now dominates many, if not most, wetlands in the Calumet region (Choi 2002, this volume), may not provide useful habitat for most species. Areas densely dominated by cattails (*Typha latifolia*), which also are very common, provide marginally better habitat structure. Here, however, poor water quality and dense layers of cattail thatch are the limiting factors preventing amphibian and reptile colonization. Some common species, such as garter snakes, may enter the riparian wetlands on occasion.

Stands of young floodplain forest, characterized by pioneer species such as cottonwood and usually by a dense understory, are present at several locations along the river margin. These habitats are largely impenetrable. If wetlands isolated from the river exist in the cottonwood thickets, they could be used by some common amphibian species for breeding, but the sites are probably too heavily overgrown and shaded for most reptiles.

ADJACENT SITES

While the Grand Calumet River and bordering riparian wetlands support a depauperate herpetofauna, several natural areas near the river are noted for their species richness. Some parcels of lesser quality also support amphibians or reptiles tolerant of habitat modification. These sites are described below on a reach-by-reach basis from east to west.

Grand Calumet Lagoons reach.—The lagoons at the easternmost end of the Grand Calumet River (site 16 in Fig. 2) are partially bordered on the north and south by Miller Woods, which is part of Indiana Dunes National Lakeshore. Areas immediately south of the lagoons consist largely of dry-mesic sand savanna with interspersed marsh and pond communities in swales. The area to the north is a diverse dune complex in immediate proximity to Lake Michigan and includes unusual communities such as pannes (Wilhelm 1990). The Miller area is located in a transition from the more mesic, sheltered areas (which become increasingly more common) to the east, and the more open and increasingly prairie and savanna dominated sites to the west.

Specimens of amphibians and reptiles collected from the Miller area are available from as early as 1902. Several prominent scientists, including Carl Hubbs, Karl P. Schmidt, and Walter Stille, visited the area during the first half of the 20th century. However, locality data for these early specimens are usually vague and many of them may have been collected outside of the current boundaries of the National Lakeshore. More recent data (Table 2), gathered in the mid-1980's, is available from Resetar (1988) and Werth (1990). The study site (Site 15 in Fig. 2) of Werth (1990) was located a little more than 1 km south of the Lagoons, but the site included habitat representative of the general area.

Resetar (1988) listed 18 species of amphibians and reptiles occurring within Miller Woods (area around Site 15 in Fig. 2) at the time of his study. One of these, Fowler's toad, is characteristic of the pannes and blowouts north of the Grand Calumet Lagoons, though the other 17 species are more general in occurrence. All 18 species could occur in the immediate proximity of the lagoons. Only two other sections of the National Lakeshore, the Cowles Bog Unit and the Eastern Unit (both well east of the Grand Calumet River), support greater herpetofaunal species richness (Resetar 1988).

Additional species have been reported historically from Miller Woods (Site 15 in Fig. 2) and surrounding areas (now largely converted to industrial, commercial, and residential development), but are not documented from Miller Woods within Indiana Dunes National Lakeshore (*Acris crepitans blanchardi*, *Coluber constrictor*, *Elaphe v. vulpina*, *Eumeces fasciatus*, *Nerodia sipedon*, *Plethodon cinereus*, *Rana pipiens*, and *Thamnophis r. radix*). In Miller Woods, these species may be present but as yet undocumented, locally extirpated, or still present in habitat remnants outside of Miller Woods *per se*. *Acris crepi-*

Table 2.—Species of amphibians and reptiles from Miller Woods (Site 15) recorded by Resetar (1988) and Werth (1990).

Frogs and toads
- *Bufo fowleri* (Fowler's toad)
- *Hyla versicolor* (Gray tree toad)
- *Pseudacris c. crucifer* (Spring peeper)
- *Pseudacris t. triseriata* (Western chorus frog)
- *Rana catesbeiana* (Bullfrog)
- *Rana clamitans melanota* (Green frog)

Salamanders and newts
- *Ambystoma laterale* (Blue-spotted salamander)
- *Ambystoma tigrinum tigrinum* (Eastern tiger salamander)
- *Notophthalmus viridescens* (Eastern red-spotted newt)

Snakes
- *Heterodon platirhinos* (Eastern hognose snake)
- *Storeria dekayi wrightorum* (Midland brown snake)
- *Thamnophis proximus proximus* (Western ribbon snake)
- *Thamnophis sirtalis sirtalis* (Eastern garter snake)

Turtles
- *Chelydra s. serpentina* (Common snapping turtle)
- *Chrysemys picta marginata* (Midland painted turtle)
- *Emydoidea blandingii* (Blanding's turtle)
- *Sternotherus odoratus* (Common musk turtle)

Lizards
- *Cnemidophorus sexlineatus* (Six-lined racerunner)

tans blanchardi and *Rana pipiens* have disappeared from many historical localities in northwestern Indiana. Wilhelm (1990) noted that many of the locales in the general Miller area that were visited by early botanists have been destroyed. The existence of *Plethodon cinereus* labeled "Miller" in a museum collection implies that (as Wilhelm (1990) suggests) mesic forest pockets once existed near Miller Woods. This species is still common near Dune Acres (15 km east of Miller Woods) where the required habitat is present.

USX reach.—The USX (United States Steel Corporation) reach (Site 14 in Fig. 2) of the Grand Calumet River corridor includes some remnant ridge areas with black oak as well as successional species such as cottonwood. A botanical survey would help determine the extent of potential reptile habitat. If this site is used to bury contaminated sediments or materials, more research, including flora and fauna, would be useful. An effort to relocate animals prior to construction could be considered.

Gary Sanitary District reach.—The Clark and Pine complex (Sites 10–12 in Fig. 2) of seven sites is located north of the Grand Calumet River at the eastern end of the Gary Sanitary District reach and extends slightly into the adjacent USX reach. The seven natural areas may include perhaps the highest concentration of rare and endangered plant and animal species remaining in Indiana (Bowles 1989). Although only Clark and Pine East directly borders the Grand Calumet River, several of the areas are divided from each other only by railroad tracks or roads, and to some extent, they probably still function as a unit. Several of the ponds studied by Shelford (1913) were within or near the Clark and Pine complex. Other collectors, such as Hubbs and Meeks, also collected in the general area; and specimens are available from as early as 1902.

Clark and Pine East (site 12 in Fig. 2—area east of Clark Street), sometimes referred to as the Bongi site, borders the Grand Calumet River just east of the U.S. Route 12 bridge and extends to the north. The approximately 102 ha site was acquired by the Division of Nature Preserves, Indiana Department of Natural Resources, in 1993. The area was originally a classic example of ridge and swale habitat. At various times in the past, several of the ridges were mined for sand. The resulting low, wet, flat areas subsequently revegetated mostly with native species, including an unusual panne-like assemblage. Relatively undisturbed-but-overgrown sand savanna alternates with swales in the east-central part of the site. Management of Clark and Pine East continues and consists largely of brush clearing and controlled burning. Amphibians and reptiles were inventoried during 1990 and 1991 by Mierzwa et al. (1991) as part of the Illinois-Indiana Regional Airport Study. The most intensive inventory effort, including quantitative drift fence sampling using pitfall and funnel traps (see Heyer et al. 1994 for a detailed discussion of drift fence techniques), was focused within a complex of dry-mesic sand savanna, mesic to wet sand prairie, marsh, and shrub swamp in the least disturbed portion of the site. During each visit to the site, visual sweep searches were also carried out in other parts of the site.

The 17 ha Clark and Pine Nature Preserve (Site 11 in Fig. 2) is located just northwest of Clark and Pine East. The two sites are separated by Clark Street. The Nature Preserve has been under state ownership for some time and has been intensively managed. The nature preserve is generally wetter and more open than Clark and Pine East with extensive areas of pond, marsh, sand prairie, and open sand savanna. The sand savanna includes both black oak (*Quercus velutina*) and jack pine (*Pinus banksiana*); the plant communities were described in detail by Bowles (1989). Clark and Pine Nature Preserve was sampled for amphibians and reptiles by Resetar (1988), using a combination of drift fence and visual sweep searches.

Other sites within the complex are privately owned. Lakeshore Railroad Prairie, a small site located just to the north of Clark and Pine East, has pond, marsh, panne, sand prairie, and sand savanna communities, the latter dominated by jack pine. Clarke Junction East and Clarke Junction West (Site 10 in Fig. 2) are located northwest of Clark and Pine Nature Preserve. These sites also include pond, marsh, panne, and sand prairie communities but suffer from shrub encroachment. Limited information on the herpetofauna of these sites, based on only a few visits, is included in Mierzwa et al. (1991). Morgan & Burling (1979) visited several Clark and Pine complex sites and reported the presence of some amphibians and reptiles, but their lists include at least one apparent misidentification and will not be included here. The list of amphibians and reptiles observed by Mierzwa et al. (1991) and Resetar (1988) within the Clark and Pine complex is presented in Table 3. Eighteen species occur within the complex at present, an unusually high number for a relatively small site. Unusual species include *Acris crepitans blanchardi* (a once common species that has nearly disappeared from northern Indiana) and the state-endangered *Clemmys guttata*.

Table 3.—The amphibians and reptiles observed by Mierzwa et al. (1991) and Resetar (1998) within the Clark and Pine complex (Sites 10-12).

Frogs and toads
- *Acris crepitans blanchardi* (Northern cricket frog)
- *Bufo americanus* (American toad)
- *Pseudacris t. triseriata* (Western chorus frog)
- *Rana catesbeiana* (Bullfrog)
- *Rana clamitans melanota* (Green frog)

Salamanders and newts
- *Ambystoma t. tigrinum* (Eastern tiger salamander)
- *Notophthalmus viridescens* (Eastern red-spotted newt)

Snakes
- *Lampropeltis triangulum* (Milk snake)
- *Nerodia sipedon* (Common water snake)
- *Storeria dekayi wrightorum* (Midland brown snake)
- *Thamnophis p. proximus* (Western ribbon snake)
- *Thamnophis s. sirtalis* (Eastern garter snake)

Turtles
- *Chelydra s. serpentina* (Common snapping turtle)
- *Chrysemys picta marginata* (Midland painted turtle)
- *Clemmys guttata* (Spotted turtle)
- *Emydoidea blandingii* (Blanding's turtle)

Lizards
- *Cnemidophorus sexlineatus* (Six-lined racerunner)
- *Ophisaurus a. attenuatus* (Western slender glass lizard)

A few additional species have been reported from the general vicinity of Clark and Pine, but their presence is based either on old museum specimens or on more recent anecdotal reports without specimen documentation. These species are: *Ambystoma laterale* (1978), *Bufo fowleri* (1917), *Heterodon platirhinos* (1902), *Hyla versicolor* (1904), and *Regina septemvittata* (1990). If any of these species are documented, that would only enhance the notable diversity of the site.

Little is known of the herpetofauna along other portions of the Gary Sanitary District reach. Some degraded habitat is present on the Gary Airport property (Site 9 in Fig. 2), and the authors have collected *Thamnophis s. sirtalis* and *Ophisaurus a. attenuatus* there. Mierzwa et al. (1991) reported on the herpetofauna of Ivanhoe Dune and Swale (Site 8 in Fig. 2), a site owned by The Nature Conser-

Table 4.—Species reported (Mierzwa et al. 1991) for the DuPont site (Site 7 in Figure 2).

Frogs and toads
- *Bufo americanus* (American toad)
- *Pseudacris triseriata triseriata* (Western chorus frog)
- *Rana clamitans melanota* (Green frog)

Salamanders and newts
- *Ambystoma t. tigrinum* (Eastern tiger salamander)

Snakes
- *Storeria dekayi wrightorum* (Midland brown snake)
- *Thamnophis s. sirtalis* (Eastern garter snake)

Turtles
- *Chelydra s. serpentina* (Common snapping turtle)
- *Chrysemys picta marginata* (Midland painted turtle)
- *Emydoidea blandingii* (Blanding's turtle)

Lizards:
- none

vancy. Since this site is south of the Indiana Toll Road and effectively isolated from the Grand Calumet River, the Ivanhoe Dune and Swale is not addressed here.

DuPont reach.—The privately owned DuPont site (Site 7 in Fig. 2) extends along the northern bank of the Grand Calumet River between Cline and Kennedy Avenues. In addition to marsh and floodplain forest along the river, the site includes extensive areas of dry-mesic to wet sand prairie, dry-mesic sand savanna, and swales with sedge meadow and marsh. No historical information is available on the herpetofauna. The site was sampled in 1990 and 1991 for amphibians and reptiles by Mierzwa et al. (1991) using a drift fence and occasional visual sweep searches. Although the DuPont site is not as species rich as the preserves described above, a minimum of nine species lives there (Table 4). Since not all habitat types were intensively sampled, additional species may be present at the site.

An area of open marsh is located south of the Grand Calumet River, between the DuPont site and the confluence with the Indiana Harbor Canal. The marsh is directly across the river from a J-shaped channel. River water swirls through this site, which can be characterized as a partially open marsh habitat located in a river bend. The area is inhabited by *Chelydra s. serpentina* and *Chrysemys picta marginata*, which benefit from the interspersion of open water and emergent marsh.

Two high-quality natural areas, Gibson Woods Nature Preserve (Site 6 in Fig. 2) and Toleston Ridges Nature Preserve (just north of Site 6 in Fig. 2) (also known as the Shell Oil Tract) are located south of this reach. Bacone (1979) included a list of amphibians and reptiles for Toleston Ridges. However, these sites are effectively isolated by the Indiana Toll Road, so they are not presented here.

East Chicago Sanitary District reach.—An area of upland meadow (Site 5 in Fig. 2) is located south of the river between the confluence of the Indiana Harbor Canal and a substation just southeast of the East Chicago Sanitary District Plant. The meadow is dominated by a variety of herbaceous plant species, but is susceptible to overgrowth by woody species. No amphibians or reptiles were noted during a site visit, but suitable habitat is present for several upland species.

Roxanna Marsh reach.—Little information is available on amphibian and reptile populations for Roxanna Marsh (Site 4 in Fig. 2). The northern leopard frog, *Rana pipiens*, was reported at the site in 1984 (Indiana Department of Natural Resources 1992). This report represents the most recent record of the species from the Indiana portion of the Grand Calumet River watershed. The same survey recorded *Chelydra s. serpentina* and *Chrysemys picta marginata* as common in open water areas. The marsh habitat is of relatively low quality and probably supports few species of amphibians and reptiles.

Hammond Sanitary District reach.—Land south of the treatment plant (Site 3 in Fig. 2) is separated from the river by a dike. Much of the area is overgrown with herbaceous vegetation. Water is ponded in some areas and supports a breeding population of toads. The site has been severely altered, but it could support additional species and might benefit from restoration or management.

Culverts reach.—This segment (area west of Site 3 in Fig. 2) has very little remaining natural area. No information is available for this segment of the Grand Calumet River and it is unlikely that any significant diversity of species remains there.

Burnham Prairie reach.—Burnham Prairie (Site 1 in Fig. 2) is located along the Grand Calumet River approximately 2.0 km to the west of the Illinois-Indiana state line. Although outside of the primary study areas, Burnham Prairie is discussed here as an example of the very different Chicago lake plain ecosystem. While the Indiana sites discussed above are on beach or near-shore sand deposits, Burnham Prairie is on silt-loam soils deposited in somewhat deeper water. This prairie is one of the last remaining examples of the black soil prairies once widespread in the Lake Calumet region and discussed at length by Cowles (1901). The site includes marsh, wet, wet-mesic, and dry-mesic prairie, and a small dry-mesic savanna grove with bur oak, *Quercus macrocarpa*. Two species that are common on the black soil site, *Rana pipiens* and *Thamnophis r. radix*, are rare a few kilometers east in northwest Indiana. Species richness is relatively low, possibly because the site is small; however, all six species found at Burnham Prairie are relatively abundant there (Mierzwa et al. 1991): *Bufo americanus*, *Pseudacris t. triseriata*, *Rana pipiens*, *Storeria dekayi wrightorum*, *Thamnophis r. radix*, and *Thamnophis s. sirtalis*.

EXTANT SPECIES

A total of 33 species of amphibians and reptiles has been recorded within the watershed of the Grand Calumet River. Seven of these were recorded historically but have not been reported recently. At least 26 species are still present. The habitat, distribution, and status of each species are briefly summarized below.

Acris crepitans blanchardi.—(Northern cricket frog). Cricket frogs are associated with the margins of permanent ponds and streams, and they must have been common at one time along the banks of the Grand Calumet River. Sometime in the late 1970's or early 1980's, this once abundant frog disappeared from most locales in the northern part of its range. A population at the Clark and Pine complex (Mierzwa et al. 1991) is the only known to persist in Lake County. Cricket frogs are quite common at both Clark and Pine Nature Preserve and Clark and Pine East, and they are frequently seen along swale edges during the summer months.

Ambystoma laterale.—(Blue-spotted salamander). This species inhabits wooded communities including relatively open savanna, woodland, mesic forest, and swamp forest. Breeding likely takes place in the swales. Blue-spotted salamanders are uncommon in the study area. Werth (1990) found one specimen at Miller Woods (Site 15 in Fig. 2). Mierzwa et al. (1991) collected two in the western part of Ivanhoe Dune and Swale (Site 8 in Fig. 2). Morgan & Burling (1979) reported one from the Clark and Pine areas (Site 10 in Fig. 2). The blue-spotted salamander is a northern species, which is near the southern limit of its range in northwest Indiana.

Ambystoma t. tigrinum.—(Tiger salamander). Although seldom seen because of burrowing habits, the tiger salamander is not uncommon in the vicinity of the Grand Calumet River. The species breeds in marsh or shrub swamp within swales and resides for the remainder of the year in dry-mesic sand savanna on the dune ridges. Individual salamanders are often found in surprisingly open locations. One Illinois population of tiger salamanders increased dramatically as savannas were opened up with brush clearing and prescribed burns (Mierzwa pers. obs.). Adult tiger salamanders usually do not travel far from breeding sites; recent studies in areas of sandy soil in New York have indicated that up to 80% of the population remains within 100 m of the breeding wetland with only a few individuals moving as far as 300 m. It is not known if these dispersal distances are to be expected in the midwestern U.S. Tiger salamanders that spend most of their time in burrows created by shrews or other other small mammals (Madison 1993) with limited surface activity on rainy nights.

Bufo americanus.—(American toad). American toads are common in the western part of the study area; and they occur at Clark and Pine, DuPont, Ivanhoe Dune and Swale, near the Hammond Sanitary District treatment plant, and at Burnham Prairie (Mierzwa et al. 1991). They have not been reported at Miller Woods. Elsewhere in northwest Indiana, populations frequently are found in river floodplains. Water quality may constrain the toads' use of Grand Calumet riparian areas, but some have been observed in swales adjacent to the river at DuPont (Site 7 in Fig. 2).

Bufo fowleri.—(Fowler's toad). This species, more characteristic of areas well to the south, is restricted to sandy soil in northwest Indiana. In the dunes area, the toad typically breeds in blowout ponds and pannes in the immediate vicinity of Lake Michigan (Breden 1988). A population at Miller Woods (Site 15 in Fig. 2), north of the Grand Calumet Lagoons, may be the westernmost extant in the dunes area. Historically, the species occurred at Clark and Pine (Site 11 in Fig. 2), where in 1917 a specimen was collected at the pond closest to Lake Michigan.

Chelydra s. serpentina—(Snapping turtle). Snapping turtles are tolerant of pollution, and they are still present in the Grand Calumet River, in riparian marshes, and in most of the nearby wetlands. Because this species is fully aquatic and seldom basks in the sun, the snapping turtle is usually more common than the available records indicate. This species has been reported from the Grand Calumet lagoons (Site 16 in Fig. 2), Miller Woods (Site 12), DuPont (Site 7), and the Clark and Pine complex (Sites 10–12). The snapping turtle is a habitat generalist that can be found in most permanent water bodies.

Chrysemis picta marginata.—(Painted turtle). Numerous records of this species exist for the study area from as early as 1909 to as recently as 1996. The painted turtle is one of the few species still found in the main channel. At times, permanent swales close to the river support dense populations, especially at Miller Woods (Site 15 in Fig. 2), DuPont (Site 7), and the Clark and Pine complex (Sites 10–12). Painted turtles inhabit both ponds and rivers, and they are easily observed because of their proclivity to bask on logs or other floating objects.

Clemmys guttata.—(Spotted turtle). This small, attractive turtle is endangered in Indiana and in Illinois. The spotted turtle is characteristic of shallow, sedge-dominated wetlands and adjacent marsh borders. The Clark and Pine complex (Sites 10–12 in Fig. 2) supports one of the largest spotted turtle populations in northwest Indiana, but the species is suffering from illegal collecting. Suitable habitat is present in swales very close to the Grand Calumet River at Clark and Pine East (Site 12). This locale is nearly at the western distributional limit of the species.

Cnemidophorus sexlineatus.—(Six-lined racerunner). This lizard inhabits xeric, sparsely vegetated dunes. Populations in northwest Indiana are widely disjunct from the main body of the range, located well to the south, and presumably represent a relict population from a time of warmer or drier climate. Although the racerunner is strictly an upland species, this lizard is found in close proximity to the river at several locations where sand prairie or open sand savanna communities persist. Recent records are available from Clark and Pine (Site 11), Brunswick Center Savanna ("Brunswick Park" south of Site 12 in Fig. 2) (Mierzwa et al. 1991; Resetar 1988), and Miller Woods (Site 15) (Werth 1990).

Emydoidea blandingii.—(Blanding's turtle). This is a federal "species at risk" (formerly "Category 2"), and Blanding's turtle is included on special concern or watch lists in most states in which it is found. Recent attention has focused on the long life span (>60 years) and late age of maturity (14–20 years) of this species (Congdon et al. 1993). Because of these life-history characteristics, loss of reproductive females via highway mortality, over-collecting, or other causes may have significant long-term effects on population viability. Blanding's turtles live at points throughout the study area; recent reports are available from Miller Woods (Site 15), Clark and Pine East (Site 12), Clark and Pine Nature Preserve (Site 11), Lakeshore Railroad Prairie (just to the north of Site 12), Ivanhoe Dune and Swale (Site 8), and DuPont (Site 7). Populations appear to be at low density at most sites. Blanding's turtles are most common in swales that include pond and marsh communities and particularly those with considerable submerged vegetation. Individuals are occasionally encountered on land. Short-term movements in excess of 800 m have been observed (Mierzwa unpubl. data), suggesting that relatively large sites may be needed to support a viable population in the long-term. Blanding's turtles have been observed in sluggish, well-vegetated rivers such as Dead River at Illinois Beach State Park and may have once inhabited the Grand Calumet River; however, early observers apparently overlooked this species. The range of the Blanding's turtle is mostly to the north of the Grand Calumet River area.

Heterodon platirhinos.—(Eastern hognose snake). The only recent report of hognose snakes has been from Miller Woods (Site 15) (Werth 1990). This species historically was found at Clark and Pine (Site 11). This upland species is found in sand prairie and sand savanna; it may occasionally forage for toads near wetland margins.

***Hyla versicolor* complex**.—Gray treefrogs are common at Miller Woods (Site 15), but the only record of their presence elsewhere in the study area is based on a 1904 specimen. A variety of semi-permanent wetlands is used for breeding; the adults spend the rest of the year in nearby trees and shrubs. Populations in northwest Indiana are thought to be *Hyla versicolor*, and the nearest report of the cryptic sibling species, *Hyla chrysoscelis*, was in Berrien County, Michigan (Bogart & Jaslow 1979).

Lampropeltis triangulum.—(Milk snake). Milk snakes are uncommon in the study area. Resetar (1988) reported the species from Clark and Pine Nature Preserve (Site 11), and Mierzwa et al. (1991) collected two specimens at Clark and Pine East (Site 12) over two field seasons. One of these was caught in a drift fence in dry-mesic sand savanna and the other was found under roadside debris along Clark Street. Elsewhere in the region, milk snakes are characteristic of upland savannas; but they are occasionally collected in sedge meadows (Mierzwa 1993).

Nerodia sipedon.—(Northern water snake). This semi-aquatic snake may have once inhabited the margins of the Grand Calumet River, but recent observations have been limited to swales in the Clark and Pine complex (Sites 10–12) (Resetar 1988; Mierzwa et al. 1991). Historically, the species was found in the Miller area, where two specimens were collected in 1902. Northern water snakes are thought to be relatively uncommon in the study area today.

Notophthalmus viridescens.—(Eastern newt). Newts are aquatic as adults, but they are capable of terrestrial movements if ponds dry. The adult phase may be preceded by a terrestrial eft stage lasting up to several years. Newts are common at Miller Woods (Site 15) (Werth 1990) and uncommon but present in the Clark and Pine area (Sites 10–12), where they were reported by Shelford (1913) and Mierzwa et al. (1991). In both areas, newts inhabit pond and marsh communities in permanent and semipermanent swales.

Ophisaurus a. attenuatus.—(Western slender glass lizard). This legless lizard is common in the more open western part of the study area. Recent observations have been mostly in xeric to dry-mesic sand prairie openings on ridges, but one specimen attempted to escape by swimming along the margin of a swale (Mierzwa unpubl. data). Extant populations are known from the Clark and Pine complex (Sites 10–12), Ivanhoe Dune and Swale (Site 8), and from disturbed areas at the Gary Airport (Site 9) (Mierzwa et al. 1991). Additional populations are probably present. Populations in the study area are disjunct and near the northern limit of the species' distribution; they may represent remnants from warmer or drier times.

Pseudacris c. crucifer.—(Spring peeper). Spring peepers are common at Miller Woods (Site 15) and in the eastern part of the dunes region where woodland and forest are widespread. In the western part of our study areas, spring peepers have been reported only from Tolleston Ridges Nature Preserve (just north of Site 6). They breed in shrub swamps, marshes, and vernal ponds; and adults summer in shrubs and trees.

Pseudacris t. triseriata.—(Western chorus frog). This species is characteristic of grassland and savanna areas. The western chorus frog is abundant in the western part of the study area, but is less common and more sporadically distributed in the eastern part. They breed in marshes; and during the summer months, adults forage in herbaceous vegetation.

Rana catesbeiana.—(Bullfrog). Bullfrogs are semiaquatic, and they are usually observed at the margins of permanent ponds or rivers. Recent records are available from Miller woods (Site 15) and Clark and Pine East (Site 12); bullfrogs are probably widespread in the area but relatively uncommon.

Rana clamitans melanota.—(Green frog). Green frogs have been observed at all Grand Calumet sites sampled in recent years, and they are relatively common at the larger natural areas. They are semiaquatic, inhabiting permanent marshes, ponds, and streams.

Rana pipiens.—(Northern leopard frog). This species is usually associated with herbaceous vegetation, including sedge meadow, wet prairie, wet savanna, and marsh. Leopard frogs were recorded in Miller Woods (Site 15) in 1922 and 1935, and from Hessville in 1923 (area south and southwest of Gibson Woods

Nature Preserve, Site 6); but the only recent report from the Indiana portion of the study area is from Roxanna Marsh (Site 4) from 1984 (Indiana Department of Natural Resources 1992). Leopard frog populations were notably absent at the Indiana sites sampled in recent years (Mierzwa et al. 1991; Werth 1990). Leopard frog populations have reportedly declined in parts of the Midwest recently (Harding & Holman 1992). At nearby Illinois sites, including Burnham Prairie (Site 1) and Powderhorn Lake (Site 2 in Fig. 2), northern leopard frogs are still common (Mierzwa et al. 1991).

Sternotherus odoratus.—(Musk turtle). Several records of this aquatic turtle exist from the Grand Calumet area. In 1918, Carl Hubbs collected a specimen that is now in the Field Museum collection from the Grand Calumet River near Miller Woods (Site 15). Other specimens are available from the Grand Calumet Lagoons (Site 16) and Buffington (by Lake Michigan in northwest Gary). Shelford (1913) listed musk turtles as characteristic of the more open swales close to Lake Michigan. The species probably still occurs in some wetlands near the river, but its benthic preference makes it hard to document. Werth (1990) found musk turtles at Miller Woods (Site 15), and a single specimen seen crossing a road in Hammond in 1996 was turned in at Gibson Woods Nature Preserve.

Storeria dekayi.—(Brown snake). This small, secretive species is the second most common snake at most locations within the study area. Most individuals were caught in drift fences or found under boards or other debris. Dry-mesic sand savanna is probably the preferred habitat of the brown snake; but some individuals have been found in sedge meadows, wet prairies, or along the margins of marshes at Clark and Pine (Site 11) (Mierzwa et al. 1991).

Thamnophis p. proximus.—(Western ribbon snake). This semi-aquatic species is characteristic of shrubby wetland margins (Rossman et al. 1996), but is uncommon in the study area. So far, the species has been reported only at Miller Woods (Site 15) and Clark and Pine Nature Preserve (Site 11) (Resetar 1988). A specimen collected near Miller Woods in 1919 was found within the "pine-oak association."

Thamnophis r. radix.—(Plains garter snake). This species is characteristic of black-soil mesic prairie. The plains garter snake is abundant west of the Illinois state line, but is extremely rare in northwest Indiana. This snake is a western species and, except for disjunct Ohio populations, is near the eastern limit of its range here. The only Indiana records from the vicinity of the study areas are from the area in or around Miller Woods (Site 15) (1902) and Hessville (south and southwest of Gibson Woods Nature Preserve, Site 6) (1923, 1935). In contrast, during a 1991 effort, 38 plains garter snakes were caught in drift fences at Burnham Prairie (Site 1); and several more were found under boards just west of Wolf Lake and just north of Powderhorn Lake (Site 2) (Mierzwa et al. 1991). Seibert (1950) studied this species in the Lake Calumet area and reported a density of 840 plains garter snakes per ha in a vacant lot near 103rd and Stony Island Avenue in Chicago (northwest of the map in Fig. 2).

Thamnophis s. sirtalis.—(Common garter snake). This snake is the most widespread and abundant snake in the Grand Calumet River Area. The species has been reported, usually in substantial numbers, from every site studied to date. In the study area, common garter snakes are abundant in dry-mesic sand savanna and in successional fields. They are easily collected from under debris in vacant lots. Common garter snakes do not hesitate to enter marshes and ponds to forage for frogs and fish. This species has been found within meters from the Grand Calumet River; and in 1996 a specimen was observed along a railroad right-of-way 50 m north of the river at Clark and Pine East (Site 12).

SPECIES NOW LIKELY EXTIRPATED

Coluber constrictor.—(Blue racer). Two old specimens from "Miller" are available (Schmidt & Necker 1935), and one of them was collected by Meek in 1908. Morgan & Burling (1979) reported a blue racer from a site southeast of, but apparently isolated from, Miller Woods (Site 15).

Elaphe vulpina.—(Fox snake). A single, undated but old specimen (Field Museum of Natural History 2864) was collected at "Miller." Given significant field effort in Miller Woods in the past 15 years without new captures, then fox snakes are either very rare or extirpated.

***Eumeces fasciatus*.**—(Five-lined skink). This lizard is known from a single old specimen collected at "Miller" (Schmidt & Necker 1935). The same consideration about rarity or extirpation for *Elaphe vulpina* applies to this skink.

***Graptemys geographica*.**—(Map turtle). Shelford (1913) mentioned map turtles from swales near Lake Michigan, and museum specimens are available from Deep River in Lake County. Although the map turtle is not documented in the immediate vicinity of the Grand Calumet River, the species may once have lived there, and this turtle certainly was present within a few kilometers of the study area.

***Necturus maculosus*.**—(Mudpuppy). Minton (2001) gives historical records of this species from Wolf Lake and Cortwright and Beamer have observed the species in Wolf Lake as recently as 2002. The mudpuppy still lives in Lake Michigan and probably entered the Grand Calumet River before the mouth closed. Poor water quality and contaminated sediments may preclude the presence of this bottom-dwelling aquatic species at present.

***Opheodrys vernalis*.**—(Smooth green snake). A single specimen (Field Museum of Natural History 2110) was collected at "Miller" in 1902. Green snakes were once common on the black soil prairies just to the west of the Illinois state line (Seibert 1950). The nearest known extant population is at Van Vlissengen Prairie, which is located just northeast of Lake Calumet (northwest of the study area, not in Fig. 2).

***Plethodon cinereus*.**—(Redback salamander). Carl Hubbs collected a redback salamander "near Miller" in 1917. This species is characteristic of mesic forest and common east of the study area in the National Lakeshore. A small area of suitable habitat was presumably present somewhere near Miller Woods at one time, but may have since been destroyed.

PROBLEMATIC SPECIES

A few additional species have been reported anecdotally; they could occur in the study area, but have not been reported or have been reported based on probable misidentifications. The spiny softshell, *Abalone spinifera*, inhabits Lake Michigan in Illinois. This turtle is not known from the study area, but could have been present historically. The queen snake, *Regina septemvittata*, was reported from Clark and Pine Nature Preserve in 1990, but the specimen was not collected (Griggs & Balzano pers. commun.). The observers were from the east coast and were not familiar with the local fauna, so the record is considered questionable; however, queen snakes are found in the headwaters of the little Calumet River in Porter County, so they could be present elsewhere in the drainage system. The pickerel frog, *Rana palustris*, was reported from the Clark and Pine complex (Sites 10–12) by Morgan & Burling (1979), but not by later investigators who spent much more time at the sites. The cool fen and wooded stream habitats frequented by this species are not present at Clark and Pine, and no other lake County records exist. Because the nearest known extant populations are several counties away, the report is problematic. Finally, a report of the massasauga rattlesnake, *Sistrurus catenatus*, from Clark and Pine East (Lake Michigan Federation 1984) must be rejected. Extensive sampling there by several people, including two with considerable massasauga experience, failed to confirm the record (Mierzwa et al. 1991). The habitat at Clark and Pine is also quite different from that typically used by the species. The report may be based on a sighting of the superficially-similar northern water snake.

POTENTIAL IMPACTS OF DREDGING

Dredging of the Grand Calumet River will have little direct impact on the amphibians and reptiles. Only two species (snapping turtle and painted turtle) are known to inhabit the channel at present. Some direct injury or mortality could result from dredging operations, but because both species are common in nearby wetlands, the river population would probably soon be supplemented from those sources. A few other species may occasionally enter the river, but these transient individuals represent a small fraction of the population primarily residing elsewhere.

Terrestrial or wetland habitat adjacent to the river could be impacted by sloughing of the banks, soil compaction by heavy machinery, or hydrological alteration related to sediment disposal. Much of the area along the river is highly degraded, e.g., with overly dense cattails and common reed, so modification of these plant communities by dredging activities is not a significant degradation of amphibian and reptile habitat. In fact, areas dense with these plant species could be improved by dredging activities if average water level were to be increased to around one meter.

The primary concern is to protect wetland and terrestrial habitat contiguous to the river at the higher quality natural areas, such as, but not limited to, Miller Woods (Site 15), Clark and Pine Nature Preserve complex (Sites 10–12), and DuPont (Site 7). These sites include rare communities used by relatively high densities of amphibians and reptiles. Several rare or uncommon species, including the state-endangered spotted turtle, *Clemmys guttata*, and state-endangered Blanding's turtle, *Emydoidea blandingii*, could occur very near the river at some of these sites.

HABITAT ENHANCEMENT AND MANAGEMENT

Considering the long history of industrial use along the Grand Calumet River, it is perhaps amazing that so many amphibians and reptiles, some of them rare, persist in the area. However, because of the presence of several high quality natural areas contiguous to the river, unique restoration opportunities are available. Appropriate management of some of the sites described above could enhance the viability of amphibian and reptile populations.

Water quality in the Grand Calumet River has improved considerably since point source pollution has been reduced; however, most of the water in the system still originates as industrial discharge or treatment plant effluent. With the removal of contaminated sediments, the Grand Calumet or riparian wetlands in direct contact with the river might eventually be able to support a herpetofaunal assemblage of at least tolerant species. Clean-up of the river will provide an opportunity to speed or expand restoration of the better quality core areas already in public ownership, to lobby for acquisition of or negotiation of management agreements for other remnants of natural land, and ultimately to take advantage of the river corridor to once again link up some of the core areas.

Several sites identified by the Indiana Natural Areas Inventory, including parts of the Clark and Pine complex, remain in private ownership and are at risk of degradation. Site 13, for example, is being obliterated by construction activities in 2002. Acquisition of these sites would help to preserve a number of rare species. Acquisition of land contiguous to core natural areas, in conjunction with restoration activities discussed below, could greatly improve the long-term viability of sites that currently support high levels of biodiversity. The best quality sites are in need of woody vegetation management, including manual removal of exotic shrubs and the regular use of controlled fire. Enforcement activities to discourage illegal dumping and poaching also would be helpful.

Because most of the landscape around the Grand Calumet River once consisted of alternating ridges and swales, some of the amphibians and reptiles in the area are capable of utilizing both upland and wetland habitat. Restoration efforts that address both habitat components are likely to support the greatest diversity of wildlife, especially if restoration areas are adjacent to the existing core natural areas. Early efforts can serve to create buffer areas for existing preserves. Over time these buffers could be extended to serve as connections between preserves. The challenges to this process will be many in this complex urban landscape, but opportunities should be pursued as they present themselves.

Wetlands with a direct river connection could contribute to enhancement of water quality and potentially provide habitat for some semi-aquatic amphibians and reptiles, such as mudpuppies, bullfrogs, green frogs, snapping turtles, painted turtles, and northern water snakes. Turtles could benefit from opening the existing dense cattail and common reed marshes in riparian areas. For this, deepening of selected areas in conjunction with dredging operations could improve interspersion of marsh and open water habitats. Restocking or natural immigration of muskrats also can thin dense stands of cattails.

Many amphibians do not breed in riparian wetlands, even if cattails and common reeds are thinned, because of fish predation on eggs and larvae. Creation of a few palustrine emergent wetlands isolated from direct contact with the river could provide habitat for these species, including tiger salamanders, American toads, western chorus frogs, and northern leopard frogs. Because groundwater generally flows toward lower and larger bodies such as the Grand Calumet River (Watson et al. 1989), wetlands of excellent quality have persisted at DuPont, Clark and Pine complex, Miller woods, and other sites, sometimes only meters from the main channel. Restored or created wetlands separated from the channel by narrow areas of upland may have a reasonable chance of maintaining good water quality and supporting a variety of plants and animals.

In addition to traditional enhancement and restoration techniques such as woody vegetation control or wetland excavation, complex but innovative opportunities are possible near the Grand Calumet River. Some areas of degraded habitat are presently of minimal value to amphibians and reptiles, but they are immediately adjacent to high quality natural areas. Areas impacted by heavy machinery movement or other dredging activity could be excavated to below the water table and then covered with clean sand, mimcking the ridge and swale topography once seen in early aerial photographs (see Fig. 1). If native vegetation can be established on both wetlands and intervening uplands, buffer or corridor areas could be established in this way. The technical feasibility of such an effort should first be carefully reviewed by appropriate specialists. Potentially suitable locations are present within the Gary Sanitary District and DuPont (Site 7) reaches, and others may be located through additional field efforts.

In Illinois, particularly near Burnham Prairie (Site 1), potential buffer restoration opportunities exist. Fill material between the river and the natural area could be excavated, assuming that it can be disposed of safely and economically; and wetlands could be established in the excavated areas. Similarly, any landfill site created for river sediments could be restored with the addition of native soil and vegetation on top of any cap material. Natural dispersal or reintroduction of animal species might then be feasible. This could be a fine opportunity to address an environmental problem and establish a semi-natural ecological system at the same time.

The Grand Calumet lagoons within and near Miller Woods may be better able to support aquatic life than more contaminated reaches to the west. After dredging operations are completed, any measures to control water movement between this and other reaches could help in maintaining suitable habitat conditions.

Corridor linkages.—Enhancement of existing riparian wetlands or restoration of wetlands in areas filled in the past could help to establish corridors linking some of the core natural areas. Such corridors would be especially useful if they included, in addition to riparian wetlands, at least a narrow upland border seeded with native grassland vegetation and scattered depressions with seasonal wetlands.

The Gary Regional Airport (Site 9), in particular, could be investigated for restoration feasibility along the river. Bordering the airport are marshes and degraded remnants of ridge and swale topography and at least one interesting and infrequently seen species, the western slender glass lizard. However, political and security considerations might constrain restoration efforts at this location. Wetlands near runways might increase the risk of bird strikes unless designed appropriately. The control tower is located near the river, and visibility during controlled burns could be an issue.

Areas adjacent to the Grand Calumet River today support a surprisingly diverse herpetofauna, although the remaining habitat is fragmented by past industrial land uses. Management and enhancement of remnant natural areas, restoration of wetlands and adjacent upland at more degraded sites, and a long-term strategy for linking or buffering core areas of open space could help maintain biodiversity well into the future.

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MAMMALS OF THE GRAND CALUMET RIVER REGION

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ABSTRACT. At least 37 of the 57 species of mammals occurring in Indiana are found in the Calumet region. These include species as follows: the opossum, 3 shrews, 1 mole, 4 bats, 1 rabbit, 7 squirrels, the beaver, 10 mice, 9 carnivores and the white-tailed deer.

Keywords: Mammals, Indiana, Calumet, distribution

The objectives of this paper are to describe the pre-settlement and present-day mammal communities of the Grand Calumet River basin and to discuss how dredging operations may affect these communities. A further objective is to present some restoration options that might be implemented during the dredging operations to enhance the mammal populations of the area.

PRE-SETTLEMENT/EARLY SETTLEMENT MAMMAL COMMUNITY

Pre-settlement records of mammals of northwest Indiana are scant and consist mainly of diary records of explorers such as Marquette and LaSalle, and of trading-post fur records. Records from the 1600s mentioned the Virginia opossum (*Didelphis virginiana*), the American beaver (*Castor canadensis*) and the bison (*Bos bison*). "Panther" (mountain lion or possibly bobcats) were reported in the 1830s. White-tailed deer were plentiful until the 1870s, but they and beavers were extirpated from the state by the turn of the century (Mumford & Whitaker 1982). Deer reintroductions began in the 1930s. There were an estimated 900 deer in Indiana by 1943, 5000 by 1951; and there were probably deer in every county by 1966. Both deer and beaver were still scarce in the 1960s but have become abundant in the last two decades in northwest Indiana and elsewhere. Wolves (possibly coyotes) were reported as late as 1914 (Lyon 1923), and black bears (*Ursus americana*) were present until about 1870.

A total of about 10 species of large mammals that were here prior to European settlement are no longer present (Table 1). Large mammals are generally most subject to extirpation when humans populate the land because they are more feared (bear, wolf, mountain lion) than smaller animals, or they are hunted and trapped (deer, elk, bison, fisher, beaver) more than smaller mammals. Also, they usually need larger tracts of undisturbed habitat. Smaller mammals live alongside humans more easily because they are not hunted and they can use smaller patches of habitat. The extirpated species are discussed below.

EXTIRPATED SPECIES

American porcupine (*Erethizon dorsatum*).—The American porcupine was clearly present in pre-settlement times; skeletal remains were found by Rand & Rand (1951). The last known specimen was from 1918.

Gray wolf (*Canis lupus*).—There are several reports of timber wolves from Indiana, but there is some question as to whether they were wolves or coyotes. The last report of a timber wolf in the state was in 1908 (Mumford & Whitaker 1982).

Black bear (*Ursus americanus*).—There are records of black bears in the area in the pre-settlement records, and Rand & Rand (1951) found skeletal remains of black bear. The last report of a bear living in Indiana was in 1850. The last time a bear was seen in the Calumet region was in 1871, but that individual was apparently a stray driven south from Michigan by a great fire (Brennan 1923).

Fisher (*Martes pennanti*).—Rand & Rand (1951) found fisher remains in the region, indicating that they were clearly present. The last report of a fisher in Indiana was in 1859 (Mumford & Whitaker 1982).

River otter (*Lutra canadensis*).—The last record of the river otter in northwest Indiana

Table 1.—Mammals taken by Mierzwa et al. (1991) in traps in the Grand Calumet River Basin. Area 1 = Dupont; 2 = Clark and Pine; 3 = Ivanhoe; 4 = Big Marsh/Indiana Ridge; 5 = Burnham Prairie/ Powderhorn Prairie, 6 = Egger's Woods. A trap-night is one trap set for one night.

	Gray area			Lake Calumet area			
	1	2	3	4	5	6	Total
Trap-nights	1388	1444	1426	1310	1352	1265	8185
Virginia opossum	0	0	0	0	0	1	1
Masked shrew	0	0	0	4	20	11	35
Short-tailed shrew	4	1	0	0	4	0	9
Gray squirrel	7	0	2	0	2	12	23
Franklin's ground squirrel	1	0	0	1	0	0	2
White-footed mouse	12	35	4	2	6	8	67
Prairie deermouse	6	1	0	23	0	0	30
Meadow vole	1	3	0	8	13	0	25
House mouse	0	0	0	1	0	0	1
Norway rat	0	0	0	1	0	0	1
Totals	31	40	6	40	45	32	

is from 1900. Otters were reintroduced into Indiana at several localities between 1995 and 1999; they could be reintroduced or make their own way into the Calumet region.

Mountain lion (*Felis concolor*).—Panthers were reported in the 1660s, and the last mountain lion recorded from Indiana was seen in 1830. There is some question as to whether it was identified correctly.

Canada lynx (*Felis lynx*).—The last Canada lynx in the region was reportedly killed by Hunter Green in 1873 at Tremont, although the identification of this species in Indiana has been questioned. The last record in the state is from 1880.

Bobcat (*Felis rufus*).—The bobcat is rare in Indiana, but there have been 42 confirmed reports in the state since 1970. It is possible that this species still occurs at the Indiana Dunes National Lakeshore (INDU), but the last record there was in 1888.

Bison (*Bison bison*).—The bison was present in northwest Indiana until well into the 19th century. The last record was in 1850.

American elk (*Cervus canadensis*).—Rand & Rand (1951) found skeletal material of elk at INDU.

All but two of the species of mammals now present were probably present in pre-settlement times. The exceptions are the old world rats and mice: the housemouse, *Mus musculus*, and the Norway rat, *Rattus norvegicus*. They are exotics that arrived in North America on ships with the early settlers. Another species possibly present now that was absent in pre-settlement times is the western harvest mouse, *Reithrodontomys megalotis*. It moved across Illinois between 1953–1969 and into Newton County, Indiana around 1969, where it was first found at Willow Slough Fish and Wildlife Area (Whitaker & Sly 1970). By 1974 (Ford 1977), this species occurred in at least seven counties, but it had not crossed the Kankakee River. If it is not already in the vicinity of the Grand Calumet River, the harvest mouse will likely make its way across the Kankakee to the Grand Calumet area relatively soon.

MAMMALS CURRENTLY PRESENT OR LIKELY TO BE PRESENT

Much information is available on mammals of Indiana (Mumford & Whitaker 1982), Illinois (Hoffmeister 1989) and INDU (Whitaker et al. 1994); but little is available specifically on mammals of the Grand Calumet River basin. Three papers present data from areas actually within the Grand Calumet River basin: Whitman et al. 1990), Mierzwa et al. (1991), and Whitaker et al. (1994).

Whitman et al. (1990) found 16 species of mammals at Miller Woods: opossum, short-tailed shrew, masked shrew, eastern mole, cottontail, white-footed mouse, prairie deer mouse, meadow vole, muskrat, fox squirrel, gray squirrel, thirteen-lined ground squirrel, red squirrel, raccoon, long-tailed weasel and white-tailed deer.

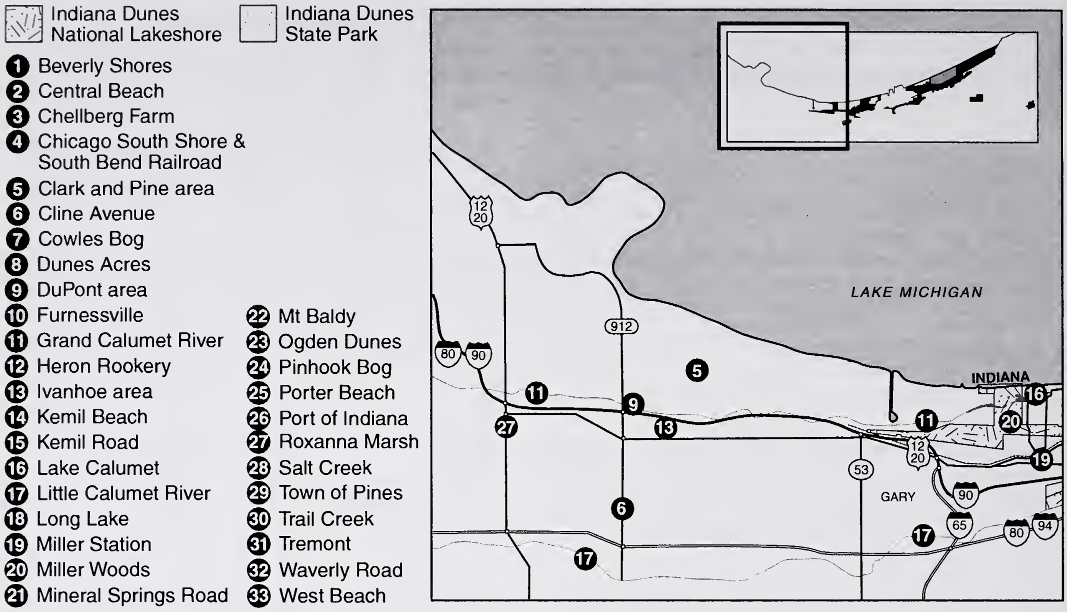

Figure 1.—The Grand Calumet River area that parallels the shore of Lake Michigan. Sites mentioned in the text are indicated by the numbers.

Mierzwa et al. (1991) studied mammals at 15 sites in five different study areas in northeastern Illinois and northwest Indiana as possible sites at which to establish an airport. Two of the areas were in the Grand Calumet River area: one in Gary, the other near Lake Calumet. However, they reported only 10 species of mammals in these two areas (Table 1): Virginia opossum, masked and short-tailed shrews, gray and Franklin's ground squirrels, deer and white-footed mice, meadow vole, house mouse and Norway rat.

Whitaker et al. (1994) included information on Miller Woods, but otherwise they did not study areas within the Grand Calumet River basin; however, the habitats, and therefore the mammals, of the Grand Calumet River basin are similar to those of INDU. Therefore, information from that work and from other papers on the Indiana Dunes was used extensively in this work.

The first significant publication on the mammals of the Indiana Dunes was by Lyon (1923). Lyon reported 22 species: opossum, short-tailed shrew, eastern mole, eastern red bat, eastern cottontail, eastern chipmunk, woodchuck, thirteen-lined ground squirrel, fox squirrel, red squirrel, prairie deer mouse, white-footed mouse, prairie vole, woodland vole, muskrat, Norway rat, house mouse, red fox, raccoon, long-tailed weasel, mink and striped skunk. He did not personally observe specimens of eastern mole, muskrat, Norway rat, raccoon (a few were taken for fur each year) or long-tailed weasel. He apparently felt these records were reliable. That he personally saw no raccoons would indicate that this species must have been uncommon at that time. He reported that white-tailed deer, although extirpated for many years, had been fairly numerous around 1875. Lyon reported that the white-footed mouse was the most abundant mammal at INDU, and it was especially abundant in wooded dunes, swamps and marshes. From foredunes he reported prairie deer mice and a few house mice. From interdunal meadows, he reported white-footed mouse, prairie deer mouse, prairie vole, pine vole and short-tailed shrew. Lyon did not take the masked shrew, the meadow vole or the meadow jumping mouse. In addition to the 22 species that he observed, Lyon (1923) listed nine species as "almost certain to be found": little brown myotis, northern myotis (Keen's myotis until recently), big brown bat, silver-haired bat, hoary bat, meadow vole, meadow jumping mouse, southern flying squirrel and gray squirrel. He listed six species as probably oc-

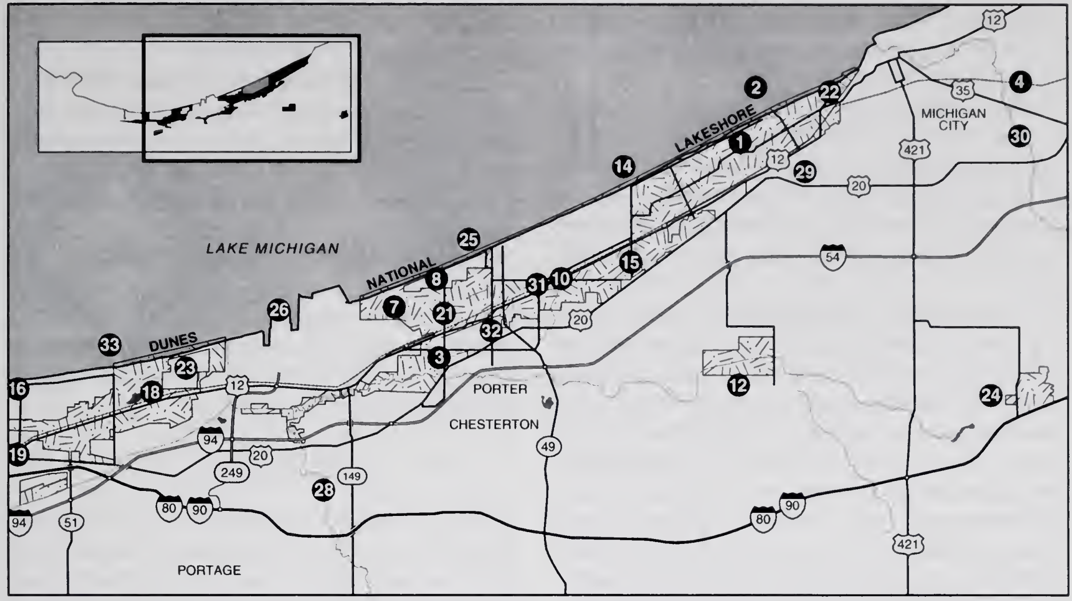

Figure 1.—Continued.

curring: star-nosed mole, least shrew, masked shrew, southern bog lemming, American badger and coyote. Lyon listed 11 species as "not now extant but whose remains may possibly be found," as "extinct," or as "probably extinct,": timber wolf (*Canis lupus*), fisher (*Martes pennanti*), black bear (*Ursus americanus*), river otter (*Lutra canadensis*), mountain lion (*Felis concolor*), Canada lynx (*Felis lynx*), bobcat (*Felis rufus*), porcupine (*Erethizon dorsatum*), snowshoe hare (*Lepus americanus*), bison (*Bison bison*), and elk (*Cervus canadensis*). We have listed evidenced extirpated species of the Grand Calumet basin except for the snowshoe hare, for which presence we find no evidence.

Brennan (1923) relates early reports of bison, black bear, mountain lion, Canada lynx, bobcat, white-tailed deer (the last one shot was in the early 1870s), elk, coyotes (Brennan cited many reports of timber wolves, and stated that there were a few left between Dunes Park and Michigan City until 1919. It is suspected by Whitaker et al. (1994) that all or many of these were actually coyotes.), porcupine, river otter, and beaver. Brennan reported several mammals as still present as of 1923: opossum, red fox (near the Furnessville Blowout), gray fox, raccoon, mink (in streams and marshes), eastern skunk, muskrat (thousands in the marshes), cottontail (common), eastern mole (exceedingly common as indicated by burrows), woodchuck (thousands present), red squirrel, gray squirrel, badger, and fox squirrel.

Lyon (1936) reported the least shrew, masked shrew, silver-haired bat, Franklin's ground squirrel, meadow vole, meadow jumping mouse and badger from the Lakeshore. Rand & Rand (1951) reported skeletal remains of 32 species of mammals in blowouts in Indiana Dunes State Park, including 26 species still present: opossum, masked shrew, northern short-tailed shrew, eastern mole, silver-haired bat, big brown bat, eastern red bat, eastern cottontail rabbit, eastern chipmunk, woodchuck, thirteen-lined ground squirrel, Franklin's ground squirrel, fox squirrel, red squirrel, southern flying squirrel, white-footed and prairie deer mouse, meadow vole, muskrat, southern bog lemming, Norway rat, house mouse, raccoon, least weasel, long-tailed weasel, mink and striped skunk. They also reported six extirpated species: black bear, fisher, beaver, porcupine, elk and white-tailed deer. New species recorded by Rand & Rand were big brown bat, southern flying squirrel, southern bog lemming and least weasel, so the new total species number from the area was 34.

A Texas Instruments team studied the Cowles Bog area from 1975 to 1980, and they collected or observed 25 species of mammals. Some of their more interesting records include the little brown bat, woodland vole, and least weasel. Surprisingly, they failed to capture any prairie deer mice, meadow voles, or prairie voles. Species reported for the first time from the area by Texas Instruments were the little brown bat and the white-tailed deer, making a total of 36 species known from the area.

Krekeler (1981) stated that the gray squirrel had been extirpated at one time but is now common in certain areas. He also indicated that the beaver had been extirpated but reintroduced, and it had caused high water problems at Dune Acres. His was the first definite recent record of the beaver at the Lakeshore. Krekeler states that skunks forage on the beach and that tracks of the white-tailed deer are now regularly seen at the Lakeshore. These additional species bring the total number of species recorded at the Lakeshore to 37.

Whitaker et al. (1994) reported opossum, two species of shrews (masked and northern short-tailed), eastern mole, three bats (red, silver-haired and big brown), eastern cottontail, seven squirrels (chipmunk, woodchuck, thirteen-lined ground squirrel, and fox, gray, red and southern flying squirrels), beaver, eight mice and rats (white-footed mouse and prairie deer mouse, Norway rat, house mouse, prairie, woodland and meadow voles and meadow jumping mouse), ten species of carnivores (coyote, red and gray foxes, raccoon, long-tailed and least weasels, mink, American badger, striped skunk and feral cat) and white-tailed deer. Gray fox brought to 38 the number of species known to the Lakeshore.

The diverse habitats of the Lakeshore thus create a home for approximately 38 of the 57 species of mammals presently known to occur in Indiana. Franklin's ground squirrel was probably present at the Lakeshore through the 1940s, but then it apparently disappeared. However, it was recorded in the Grand Calumet River basin by Mierzwa et al. (1991). Feral dogs and cats are present, and they may partially fill the predator niche. Signs of bobcat (state endangered) have been reported in the Heron Rookery area of the Lakeshore, but their presence has not been verified.

Species of mammals suspected to currently reside in the Grand Calumet River basin are discussed below and are indicated in Table 2.

DIDELPHIDAE

(opossums)

Virginia opossum, *Didelphis virginiana* Kerr.—The opossum is common in the Lakeshore area, and likewise it is surely common throughout the Grand Calumet River region. It was found in 10 of the 24 habitats sampled at INDU, and 93 were recorded as roadkills (Whitaker et al. 1994). Texas Instruments, Inc. found this species in all six of the terrestrial habitats they sampled, and Whitman et al. (1990) commonly found it at Miller Woods. Mierzwa et. al. (1991) recorded one in Egger's Woods near Wolf Lake.

INSECTIVORA

(shrews and moles)

The Insectivora consists of the moles and shrews, six species of which conceivably could occur in the Grand Calumet River area: four species of shrews and two of moles. The presence of only three species of shrews (masked, short-tailed and least) and one mole (eastern) have been confirmed there.

Northern short-tailed shrew, *Blarina brevicauda.*—The short-tailed shrew is one of the most common mammals in northwest Indiana, and it is common in the Grand Calumet River basin (Mumford & Whitaker 1982; Krekeler 1981; Texas Instruments 1975–80; Whitman et al. 1990; Whitaker et al. 1994). Whitaker et al. (1994) took short-tailed shrews in 17 of the 24 habitats studied. They were most abundant in upland terrestrial shrubland, wet prairie, old field, ephemeral lowland forest and mixed deciduous savanna. Mierzwa et al. (1991) trapped nine short-tailed shrews: four at the DuPont area, four at the Burnham Prairie/Powderhorn Prairie area, and one at the Clark and Pine area.

Least shrew, *Cryptotis parva* (Say).—The least shrew is a small, brownish short-tailed shrew, much smaller than *Blarina.* Its total length is only about 63–88 mm; its tail is only 11–20 mm. It usually is found in fairly dry open fields. It occurs throughout Indiana, but it is not taken often. There are few records in the northern part of the state. Lyon trapped a least shrew in "subdunal woods" on 31 October 1924. It was apparently from Tremont, as Sanborn (1925) reported that Lyon took one there in the fall of 1924. The specimen was deposited in the U.S. National Museum (#240630). Whitaker et al. (1994) did not take it at INDU, but it most likely lives sparingly in dry fields in the Calumet River area.

Masked shrew, *Sorex cinereus* Kerr.—The masked shrew is common in several habitats at INDU and in the Grand Calumet River area, especially in wet areas. Mierzwa et al. (1991) captured 35 individuals in their Lake Calumet study area: four in the Big Marsh/Indiana Ridge area, 20 in the Burnham Prairie/Powderhorn Prairie area, and 11 at Egger's Woods. Mumford & Whitaker (1982) found masked shrews in several habitats east of the Bailey Generating Station, and 124 of 178 mammals (69.7%) taken at Cowles and Pinhook Bogs and at Trail Creek Fen were masked shrews. Whitman et al. (1990) reported masked shrews from Miller Woods. Whitaker et al. (1994) took only 35 during their study of mammals at INDU. This included individuals from eight habitats, although they were most abundant in wet prairie (1.83 per 100 trap-nights) and marsh (1.17 per 100 trap-nights). Shrew populations were apparently low at the time of this study. The masked shrew lives in areas where the soil retains moisture sufficient to maintain burrows 100% saturated. Because of this moisture requirement, the species often lives in dense vegetation or in mossy areas.

Pygmy shrew, *Sorex (Microsorex) hoyi* Baird.—The pygmy shrew has long been presumed rare, but pitfall trapping has shown otherwise. The pygmy shrew could inhabit the Calumet River basin, but it has not been found at INDU or elsewhere in northern Indiana. It does not occur in the southern portion of the lower peninsula of Michigan either (Baker 1983). There are records from Wisconsin, including one at the extreme southeast corner, or less than 80 miles (128 km) from the Grand Calumet River area. Also, one was taken in mid-winter in a garage 50 miles (80 km) from the Grand Calumet. No pygmy shrews were taken in extensive trapping at Bailly, Cowles, or Pinhook Bogs (Mumford & Whitaker 1982); and none were taken in other areas at INDU (Whitaker et al. 1994). Thus, this shrew's occurrence in the Grand Calumet River area is unlikely. However, the unicuspid teeth of all long-tailed shrews (*Sorex*) from that area should be carefully examined. (*Sorex cinereus* has four "large" unicuspids and one small unicuspid, all easily visible from the side. *Sorex hoyi* has the third and fifth extremely reduced, thus only three unicuspids are readily visible from the side).

TALPIDAE

(moles)

Eastern mole, *Scalopus aquaticus* (Linnaeus).—The eastern mole is common at INDU (Krekeler 1981; Whitman et al. 1990; Whitaker et al. 1994) and in the Grand Calumet River region. Whitaker et al. (1994) found burrows of the eastern mole in 10 of 24 habitats examined at INDU. This species was most abundant in pine plantations, oak savanna, excavated sand, and mixed deciduous forest. The author saw a number of its burrows in the sand on 20 July 1996 at the DuPont and Clark and Pine areas in the Grand Calumet River basin. The eastern mole is common in many of the drier habitats at the Lakeshore.

Star-nosed mole, *Condylura cristata* (Linnaeus).—The star-nosed mole lives in muckland habitats. This habitat makes its burrows quite evident; burrows of eastern moles are usually in drier areas. The star-nosed mole has been documented only in the northeast portion of the state, and its range has apparently contracted in the 20th century. This species has never been taken at INDU. However, on 28 October 1982, Whitaker trapped one at Trail Creek Fen, a site east of INDU. This record suggests its presence at INDU. Muckland habitats suitable for star-nose moles are abundant in the Grand Calumet River basin, and it may occur there.

CHIROPTERA

(bats)

Twelve species of bats are found (or were found—two are probably extirpated) in Indiana, all in the family Vespertilionidae. All are nocturnal and have well-developed echolocation abilities, and all feed almost exclusively on flying insects. Little information is available on bats of INDU or northwest Indiana. There are records at INDU for only three species: big brown bat, red bat and silver-haired bat. There is an early record of the evening bat, but no recent records. There is an unverified record of the little brown myotis, but this species surely exists there. The northern myotis and hoary bat are undoubtedly present, and it is likely that the Indiana myotis is also there. Rand & Rand (1951) reported silver-haired, red and big brown bats. Information on bats of northwest Indiana is provided below. Most of these species should occur in the area of the Grand Calumet River, at least where there is adequate woodland.

Big brown bat, *Eptesicus fuscus* (Beauvois).—Whitaker et al. (1994) found one big brown bat in a large building north of Route 12 and west of Mineral Springs Road, and a post-lactation colony is located behind the barn doors at Chellberg Farm. A total of 113 bats emerged from behind this door on 27 August 1988. Several maternity colonies were found by Whitaker et al. (1994): 1) about 100 individuals in a brick house 0.2 miles east of 33E on U.S. Route 20; 2) about 20 individuals at the Lutheran Church at the south end of Mineral Springs Road (just north of I-94); 3) about 80 individuals on 9 September 1988 at the Portage Park barn, southwest of I-94 and State Road 249; 4) 43 individuals in the soffit of an old but well-preserved brick house near U.S. Route 49 north of Route 6. There are undoubtedly many maternity colonies of big brown bats in buildings in the Grand Calumet basin. This is the only species likely to winter (hibernate) at INDU, since it is the only species in Indiana that hibernates in buildings.

Red bat, *Lasiurus borealis* (Muller).—Lyon (1923) observed a female red bat roosting in blackberry bushes in the Lakeshore region. Whitaker (Mumford & Whitaker 1982) shot a female red bat at daybreak on 26 August 1963 as it was flying over the beach in what is now the Lakeshore. Whitaker et al. (1994) recorded several red bats: 1) a young female collected in July of 1987 at the West Beach bathhouse; 2) an individual observed flying at Indiana Dunes State Park on 27 August 1988; and 3) two individuals netted (1♂, 1♀) over Dunes Creek, Indiana Dunes State Park, on 23 September 1988. The red bat is solitary and hangs in trees during the daytime. It is one of the most common bats in wooded areas of northwest Indiana, and it should inhabit areas of the Grand Calumet River basin where enough trees are present.

Little brown myotis, *Myotis lucifugus* (LeConte).—Neither Lyon (1936) nor Mumford & Whitaker (1982) recorded the little brown myotis in Lake, Porter or LaPorte Counties. The only specific record of this species at INDU is that of Texas Instruments (1975–80), but this record needs verification. The author has often seen small bats flying about over openings in Indiana Dunes State Park and vicinity which could be this species or the northern myotis, *Myotis septentrionalis*. The little brown myotis migrates to the karst regions of southern Indiana where it hibernates in caves.

Silver-haired bat, *Lasionycteris noctivagans* (LeConte).—Hahn (1909) reported this species from Michigan City, LaPorte County. Mumford & Whitaker (1982) reported three individuals taken at the Indiana Dunes State Park: a female on 24 September 1928 by W.A. Weber, and two individuals on 3 May 1936 by J. Schmidt. Whitaker et al. (1994) netted one individual on 9 September 1988, about one mile northeast of the visitor center at INDU.

The silver-haired bat is a migratory solitary bat. It spends the summer and has its young north of Indiana and then migrates south. A few individuals hibernate in caves or mines in southern Indiana, but most winter in southern states. This species is fairly common in Indiana during migration from about 18 April to 28 May and from about 29 August to 6 November, when it should be relatively common at the Lakeshore (Mumford & Whitaker 1982).

Evening bat, *Nycticeius humeralis* (Rafinesque).—Russell E. Mumford shot an evening bat two miles (3 km) northwest of Porter (Porter County) on 5 August 1958. Populations of this species have decreased greatly in Indiana in recent years, and we doubt that it is currently present in northwest Indiana. The single record could have been a stray.

BAT SPECIES PROBABLY PRESENT

Northern myotis, *Myotis septentrionalis* (Merriam).—This species has often been referred to as Keen's bat, *Myotis keenii septentrionalis*. However, populations in eastern regions of the United States are currently recognized as a separate species from populations in the western U.S. (Van Zyll de Jong 1979). The eastern species is known as the northern myotis, *Myotis septentrionalis*. There are no records of this species for any of the Lakeshore counties (Mumford & Whitaker 1982). Because wooded habitat is abundant and it is a northern species, the author suspects its presence. It forms small summer colonies under the bark of trees or in buildings, and it then migrates to caves and mines where it hibernates individually rather than in groups. Kurta (1982) found it was relatively uncommon in southern Michigan, and Long (1974) reported it as less common than the little brown myotis in the Lake Michigan drainage.

Hoary bat, *Lasiurus cinereus* (Palisot de Beauvois).—Like the red and silver-haired bats, this is a solitary, migratory species that roosts in trees. It is the largest and one of the most colorful bats of Indiana. It occurs throughout the state, but it is not common anywhere. It probably lives in the Grand Calumet River basin in areas with adequate trees.

Indiana myotis, *Myotis sodalis* (Miller & Allen).—The Indiana myotis is listed as endangered. There are no records for the northwestern 15 or so counties of the state (Mumford & Whitaker 1982); however, Kurta (1982) recorded this species, and Kurta et al. (1993) later recorded a maternity colony of this species from southern Michigan. The Indiana myotis is probably present in northwest Indiana in areas forested with large trees, including the Grand Calumet River area. It forms small summer colonies under the bark of dead trees, often along watercourses. It hibernates in large numbers in a very few caves, some of which are found in southern Indiana.

LAGOMORPHA
(rabbits and hares)

Eastern cottontail, *Sylvilagus floridanus* (Allen).—The eastern cottontail is the only lagomorph in northwest Indiana. Lyon (1923), Krekeler (1981), Texas Instruments, and Whitaker et al. (1994) all listed it as common in the area of INDU. It was observed occasionally in Miller Woods by Whitman et al. (1990). Fecal pellets and tracks are commonly seen throughout INDU, and 65 cottontails were recorded as roadkills (Whitaker et al. 1994). This species was often seen by Mierzwa et al. (1991) at Clark and Pine, Lakeshore Railroad Prairie, and DuPont and Burnham Prairie. Cottontails are fairly common in the Grand Calumet River basin.

RODENTIA
(rodents)

Rodents constitute the largest group of mammals in northwest Indiana (and in the world) in number of species and individuals. The total number of rodent species includes seven species in the squirrel family; the beaver; two sigmodontine rodents (= old Cricetinae), both of which are in the genus *Peromyscus*; four or five species of arvicoline rodents (= old Microtinae; muskrat, three voles and probably the bog lemming); two Old World rodents (Murinae), the Norway rat and the house mouse; and the meadow jumping mouse (Zapodinae, Dipodidae).

SCIURIDAE
(squirrels)

There are seven species of squirrels in northwest Indiana, including the state-endangered Franklin's ground squirrel. Squirrels are some of the most conspicuous mammals, partly because most are diurnal. The largest member of the squirrel family is the woodchuck. Also, there are many fox and red squirrels at INDU. Besides being diurnal, these two are common and quite noisy. The gray squirrel and chipmunk are obvious where common. The flying squirrel may often be common, but it is seldom observed because it is nocturnal. The thirteen-lined ground squirrel has a spotty distribution, but it is found at several INDU localities (Whitaker et al. 1994). Gray and Franklin's ground squirrels have been documented within the Grand Calumet River basin (Mierzwa et al. 1991). The various squirrels are discussed below.

Eastern chipmunk, *Tamias striatus* (Linnaeus).—The chipmunk is common in many of the wooded habitats of northwest Indiana, although it is sporadic in occurrence. Lyon (1923) stated that "chipmunks do not appear to be very common in the dunes." Krekeler (1981) listed it as abundant in open woods, thickets and suburbs. Texas Instruments (1975–80) recorded numerous captures of chipmunks in several habitats. Whitman et. al. (1990) did not mention them in their Miller Woods report. Whitaker et. al. (1994) captured 24 chipmunks in nine habitats at INDU, and sign or sight observations were made in 11 plots in seven habitats. Seventeen roadkills were seen, and numerous individuals were seen elsewhere at INDU. The chipmunk should be fairly common in the Grand Calumet River basin, but Mierzwa et al. (1991) did not report it.

Woodchuck, *Marmota monax* (Linnaeus).—Lyon (1923) & Whitaker et al. (1994) commonly found woodchucks in several habitats at INDU. Whitman et al. (1990) does not mention them from Miller Woods, but Mierzwa noted them from DuPont and Burnham Prairie.

Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus* (Mitchell).—Lyon (1923) found this species "not uncommon along the Chicago, Lake Shore and South Bend Railway just south of the dunes," and reported one "just north of Oak Hill Station and a few feet above the subdunal swamp." Krekeler (1981) listed it as "common" at INDU and indicated its habitat as "pastures, road borders, dunes, weedy or cultivated fields." Texas Instruments (1975–80) reported three individuals: two from Cowles Bog and one from the transmission corridor. Whitman et al. (1990) saw this species along the railroad bed "at the north end of the study area." Whitaker et al. (1994) found a roadkill individual on Wagner Road north of Route 20, and two additional roadkills south of Route 20. Fifteen individuals were trapped in nine plots in four habitats: four in dry prairie, four in terrestrial shrubland, three in oak savanna, and four in coniferous savanna. Ten of the 15 were at West Beach. Mierzwa et al. (1991) saw this species only at Wolf Lake where it was common in Illinois on grassy roadsides. The species should be present in dry open areas with little ground cover near the Grand Calumet River.

Franklin's ground squirrel, *Spermophilus franklinii* (Sabine).—Neither Lyon (1923), nor Krekeler (1981), nor Texas Instruments (1975–80), nor Whitaker et al. (1994) reported Franklin's ground squirrels from INDU. Three Franklin's ground squirrels were taken by Alex Bognar, from "Miller" in Lake County, Indiana in 1947. The specimens are in the Field Museum (CNHM #'s 73872, 73873 and 73874). We assume these were near Miller Station, which is about half a mile south of Miller Woods. In 1986–87, Scott Johnson and other Indiana DNR personnel used two sets of 10 live traps to examine the area along the railroad at Miller Station for Franklin's ground squirrels. This locale is close to where Bognar collected this species, but no Franklin's ground squirrels were seen or taken there.

Mierzwa et al. (1991) trapped two Franklin's ground squirrels on low dunes between swales: one at the Dupont area and one at the Big Marsh/Indian Ridge area. Also, they commonly found it at Powderhorn Lake, and it was present at Burnham Prairie and near Lake Calumet. These records are exceedingly interesting since this species is listed as endangered in Indiana. Most of the currently known populations are along railroads, although a few are along roadsides.

Gray squirrel, *Sciurus carolinensis* (Gmelin).—Lyon (1923) did not report this species from the Lakeshore area; however, Krekeler (1981) recorded it as common in woods and suburbs, and Texas Instruments (1975–80) reported 23 from three habitats at the Lakeshore. Whitaker et al. (1994) recorded it in upland oak forest and in oak savanna and also several roadkilled individuals. Also, several were seen in black oak forest at Miller Woods, and one was observed in black oak forest at Dune Acres. Whitman et al. (1990) observed gray squirrels at Miller Woods.

Mierzwa et al. (1991) recorded 23 gray squirrels in the Grand Calumet River area: seven in the DuPont area, two in the Ivanhoe area, two in the Burnham Prairie/Powderhorn Prairie area, and 12 at Egger's Woods. This species is relatively uncommon at INDU, but it is more common in the Grand Calumet River basin.

Fox squirrel, *Sciurus niger* Linnaeus.—Lyon (1923), Krekeler (1981), Texas Instruments (1975–80) and Whitaker et al. (1994) all reported this species as common at INDU; and it is common in proper habitat in all of northwest Indiana. This species was not reported by Mierzwa et al. (1991) in their study plots, but it should be fairly common in the Grand Calumet River basin.

Red squirrel, *Tamiasciurus hudsonicus* (Erxleben).—Lyon (1923), Krekeler (1981) Texas Instruments (1975–80) and Whitaker et al. (1994) reported the red squirrel as fairly common in the wooded portions of INDU. Whitman et al. (1990) took it in traps along pond edges in Miller Woods. Mierzwa et al. (1991) found no red squirrels in the vicinity of the Grand Calumet River, and it is likely this species is rare or absent because of the lack of forest, particularly conifers.

Southern flying squirrel, *Glaucomys volans* (Linnaeus).—Lyon (1923) did not see flying squirrels but listed them as almost certainly present at INDU. Texas Instruments (1975–80) collected three from black oak/swamp forest at INDU; and Whitaker et al.

(1994) trapped two flying squirrels: one in black oak forest and one in black oak savanna. Scrubby black oak is a good habitat for flying squirrels because old woodpecker holes and other openings can be used as nest sites or refuges for this species. Flying squirrels were not reported by Mierzwa et al. (1991), and they are probably not common in the Grand Calumet area because of the lack of suitable forest. Flying squirrels feed heavily on nuts and seeds but will readily eat insect material or even young birds and their eggs.

Beaver, *Castor canadensis* Kuhl.—Beavers had nearly disappeared from Indiana by 1840 (Lyon 1936). They were reintroduced into Jasper-Pulaski and Kankakee Fish and Wildlife Areas in 1935 from Wisconsin and Michigan, and later introductions were made into other areas. Brooks (1959) knew of 326 colonies in 43 counties of Indiana. The majority were in portions of northwest Indiana, including Lake County. There is a 1968 photograph of a beaver lodge at Cowles Bog (Lindsey et al. 1969). Krekeler (1981) listed the beaver as uncommon at INDU but said that it had caused high water problems on the road leading into Dune Acres (at Cowles marsh). There is currently a beaver colony on the Salt Creek watershed, and signs of beaver were seen by Whitaker et al. (1994) on the lower portions of the Little Calumet River. There was a colony on the Little Calumet north of Chesterton, but all of those beavers have been trapped. Mierzwa et al. (1991) did not mention beaver in their studies of the Grand Calumet River area. The beaver should be a prominent species in wooded portions of a clean Grand Calumet River.

MURIDAE
(mice and rats)

Most mice and rats are currently placed in the family Muridae, which contains three subfamilies: the Sigmodontinae (previously the Cricetinae), the Arvicolinae (previously the Microtinae) and the Murinae. The Murinae are the Old World rats and mice, *Mus* and *Rattus*.

Sigmodontinae

The Sigmodontinae are native rats and mice and constitute one of the largest groups of mammals in North America, both in number of species and individuals. However, there are only two (or possibly three) species in this group in the Grand Calumet River basin, although one of them, *Peromyscus leucopus*, is the most abundant mammal there.

Western harvest mouse, *Reithrodontomys megalotis* (Baird).—The western harvest mouse was first taken in Indiana in 1969 at Willow Slough State Fish and Wildlife area in Newton County (Whitaker & Sly 1970). By 1975 it had extended its range to include at least seven counties of northwest Indiana (Ford 1975), but it had not crossed north of the Kankakee River into Lake and Porter Counties. By 1994 (Whitaker unpubl. data), it had extended its range south into Vigo County. By 1995 it had crossed the Wabash River into Clay County, and by 1997 it had crossed the Kankakee. Now that barrier has been crossed, harvest mice should become part of the fauna of northwest Indiana.

Deer mouse, *Peromyscus maniculatus* (Wagner).—The deer mouse occupies a variety of habitats ranging from woods to dry open areas. Its prime habitat in Indiana is in cultivated fields where it lives even when the fields are bare (Whitaker 1967). However, only the prairie deer mouse, *P. m. bairdii* is present in Indiana. It lives in dry open areas. It is never found in woods, although it can be abundant in savanna with open sand. Unlike all of the other species of small mammals in Indiana, its habitat is inversely related to plant cover; and it can live in areas with little or even no herbaceous vegetation, such as recently plowed or harvested fields or open sandy areas. Its prime habitat in Indiana is in cultivated fields (Whitaker 1967; Mumford & Whitaker 1982). Its tracks are often obvious in loose sand on dunes, or in light snow in plowed fields, where it emerges from one burrow and enters another. It probably inhabited areas of open sand such as on dunes in presettlement times.

Hahn (1909) recorded this species from only five counties and did not think it was common in Indiana. Evermann & Butler (1894) stated that it was abundant on the dunes along Lake Michigan. Lyon (1923) found numerous footprints of this species in the loose sand on the dunes but took few specimens. Krekeler (1981) recorded it as abundant in foredunes, grasslands, thickets and old fields. Whitman et al. (1990) found it from Miller Woods. Whitaker et al. (1994) recorded *Peromyscus maniculatus* from 10 habitats, but it was most common in dry prairie and on INDU right-of-ways. Mierzwa et al. (1991) recorded 30 individuals in open sand on Clark and Pine Complex, and stated that they were "so common at Lakeshore Railroad Prairie that we were able to find them under boards and debris without even trapping for them."

White-footed mouse, *Peromyscus leucopus* (LeConte).—*Peromyscus leucopus* is the most abundant small mammal at INDU (Lyon 1923; Texas Instruments 1975–80; Krekeler 1981; Whitman et al. 1990). Whitaker et al. (1994) took a total of 445 individuals in 22 of 24 habitats they studied and in 98 of the 168 (58.3%) plots in which they trapped. The only habitats from which the white-footed mouse was not taken were barren grounds and excavated areas, both habitats lacking plant cover. The highest numbers were taken in ephemeral lowland forest, oak upland forest, mixed deciduous savanna, mixed deciduous upland forest, coniferous savanna, and pine plantations. It is probably also the most abundant species in the area of the Grand Calumet River, as Mierzwa et al. (1991) took 67 individuals of this species and found it in every one of their study sites (Table 1).

Arvicolinae (microtines or voles)

All five species of microtines present in Indiana are probably present both at the Lakeshore and in the area of the Grand Calumet River.

Meadow vole, *Microtus pennsylvanicus* (Ord).—The meadow vole is found throughout northern Indiana where it is usually the most abundant small mammal of moist grassy meadows and wet prairies. In dry fields with sparse vegetation, it tends to be replaced by the prairie vole, *M. ochrogaster.* Lyon (1923) took prairie voles and pine voles at INDU, but inexplicably, he did not take meadow voles. Krekeler (1981) and Texas Instruments (1975–80) indicated it as abundant. Whitman et al. (1990) trapped them in low-lying areas around one pond at Miller Woods. Whitaker et al. (1994) trapped 171 individuals in 28 plots in 13 habitats. These animals were most abundant in old field and upland terrestrial shrubland. Thirty-four were taken in one plot in this latter habitat. The cover here was heavy and mainly forbs, but it included dogwood, poison ivy, roses, some young pines and few grasses. The soil was quite moist. Mierzwa et al. (1991) captured 25 meadow voles in five of their six study areas near the Grand Calumet River, but they found them most abundant at the Big Marsh/Indian Ridge site.

Prairie vole, *Microtus ochrogaster* (Wagner).—Lyon (1923) took seven prairie voles. Krekeler (1981) listed this species as uncommon in relatively dry fields with cover of grasses or weeds. Whitaker et al. (1994) took 17 individuals in eight plots in five habitats. The species was most abundant in old fields. Mierzwa et al. (1991) did not capture any prairie voles, but additional trapping in the drier grasslands of the Grand Calumet River will undoubtedly yield prairie voles. This species lives in drier and sparser vegetated areas than the meadow vole, and it is much less abundant to the north.

Woodland vole/Pine vole, *Microtus pinetorum* (Le Conte).—Lyon (1923) found many subterranean burrows probably used by this species but trapped only two woodland voles in the Indiana Dunes area. Krekeler (1981) listed it as uncommon and Texas Instruments (1975–80) caught two individuals in black oak/swamp forest. Whitaker et al. (1994) did not take any individuals in their study plots, but they did take four in pitfall traps set for this species in black oak woods. Mierzwa et al. (1991) did not take any woodland voles in studies using surface trapping methods. The woodland vole lives in underground burrows, and thus it is often under-represented in surface trapping surveys. It is found at INDU, and undoubtedly it also occurs in the area of the Grand Calumet River.

Muskrat, *Ondatra zibethicus* (Linnaeus).—The muskrat is common in the marshes, streams and ponds of northwest Indiana (Lyon 1923; Krekeler 1981; Texas Instruments 1975–80; Whitaker et al. 1994). Whitman et al. (1990) trapped it along ponds in Miller Woods. Mierzwa (pers. comm.) saw a road-killed individual on Route 12 near the Gary Regional Airport. Their population in the Calumet River basin could increase if the river is cleaned up.

Southern bog lemming, *Synaptomys cooperi* Baird.—Lyon (1923) did not record this species from INDU, but Rand & Rand (1951) recorded it based on their identification of skeletal remains. Krekeler (1981) recorded it as uncommon in areas with lush ground cover of grass and in bogs, but we do not believe that he ever saw a specimen. Texas Instruments (1975–80) did not capture any bog lemmings. Whitaker et al. (1994) did not trap any, and apparently no specimen is available as yet from INDU. Whitaker et al. (1994) did find bright green fecal pellets, probably from this species, at a razed residential site on Waverly Road on 28 February 1988. Meadow voles produce dull green or brownish fecal pellets. The name bog lemming is a misnomer. It is not primarily or even often found in wet areas. It has a broad range of habitats from woods to rank meadows and dry *Andropogon* fields.

Murinae
(introduced mice and rats)

Rattus norvegicus and *Mus musculus* are introduced exotics and are usually found in habitats created or disturbed by humans, such as in buildings or cultivated fields.

Norway rat, *Rattus norvegicus* (Berkenhout).—This is the common rat associated with garbage dumps, barns, grain storage units and suburban warehouses. It is a major pest almost everywhere that it occurs. It ruins foods and other materials and carries disease. It is common in larger cities and on farms in northwest Indiana. Lyon (1923) did not trap or see any rats but said that residents reported them. Krekeler (1981) reported them as common around farms, suburbs, and ditches. None were reported during the Texas Instruments studies. Whitaker et al. (1994) found rat droppings in abandoned buildings. Mierzwa et al. (1991) took one Norway rat at the Big Marsh/ Indian Ridge area.

House mouse, *Mus musculus* Linnaeus.—This mouse has been transported around the world by humans. In Indiana, it is very common in cultivated fields when adequate cover is available; but, unlike the prairie deer mouse, it vacates immediately once the cover is removed. The prairie deer mouse and house mouse are the primary small mammals of the Indiana corn and soybean fields (Whitaker 1967), although *P. leucopus* is sometimes present as well. The species also invades beaches, offshore islands and estuarine areas.

Lyon (1923) took two individuals, both in foredune areas; and Texas Instruments (1975–80) took five from young foredunes. Surprisingly, none were taken in any of the plots in the 24 habitats studied by Whitaker et al. (1994). Their only records were sight records at residential areas and some from Chellberg Farm. Two individuals were taken among 70 mammals from snap traps at Pinhook Bog by Whitaker and Mumford in 1978 (Mumford & Whitaker 1982). It is clear that the house mouse is not abundant along the Indiana Lakeshore, probably because of the lack of agricultural land present. The same is probably true in the Grand Calumet River basin, as Mierzwa et al. (1991) recorded only one house mouse. It was found at the Big Marsh/ Indian Ridge site.

DIPODIDAE
(jumping mice)
(previously Zapodidae)

Meadow jumping mouse, *Zapus hudsonius* (Zimmermann).—Lyon (1923) concluded that *Z. hudsonius* was almost certainly present in the Lakeshore region. Texas Instruments (1975–80) reported four individuals from young foredunes and 23 from the transmission corridor. Whitaker et al. (1994) took 15 individuals from three habitats, 13 of which came from one plot in aquatic shrublands. Whitaker and R.E. Mumford took one at Cowles Bog and five at Pinhook Bog in the fall of 1978, and one from a flat depression behind the foredunes east of the Bailly Generating Station in October of 1974. The meadow jumping mouse was not taken by Mierzwa et al. (1991), but it is undoubtedly present in the Grand Calumet River area.

CARNIVORA
(carnivores)

The raccoon is abundant and obvious, but the other carnivores of the Grand Calumet River area are difficult to assess and count. Large carnivores are much less abundant than small mammals, and they are usually among the first to disappear as humans develop the land, because of habitat loss, trapping and hunting. They are often thought of as problem animals and killed by the general public. For some species, roadkills may give us the best assessment of status.

The carnivores of northwest Indiana that may be present in the Grand Calumet River basin are grouped in five families, the Canidae (coyote, two species of foxes, domestic dog), Procyonidae (raccoon), Mustelidae (two species of weasels, mink, badger), Mustelidae (skunk), and the Felidae (bobcat, housecat).

CANIDAE

Coyote, *Canis latrans* Say.—The coyote has always been present in Indiana, but in recent years its populations have increased. There are early reports of wolves and coyotes at INDU; however, wolves are long gone and there was no confirmed record of coyotes prior to the work of Whitaker et al. (1994). These authors report that one was seen by Noel Pavlovic at Toleston Dunes on 7 August 1990, and that Lakeshore rangers have seen them several times near the Heron Rookery, starting in June and July of 1990. Dan Fagre saw one in a cornfield just south of INDU in 1991. It is not clear yet whether coyotes have taken up residence at the Lakeshore; but if not, it appears to be only a matter of time until they do. Unfortunately, Rand & Rand (1951) found no canid bones to help determine whether coyotes or wolves or both inhabited the dunes in pre-settlement times. Mierzwa et al. (1991) did not report coyotes, and it is not clear whether they now live in the Grand Calumet area.

Red fox, *Vulpes vulpes* Linnaeus.—Red and gray foxes are often confused because the gray fox has some reddish coloration. The red fox is easily identified because it is red above with a white tail tip. Lyon (1923) reported red foxes at INDU. Whitaker et al. (1994) reported them from five different habitats at the Lakeshore, and one was found dead along the roadside in 1984–85. Four were seen from a helicopter during the 1991 Lakeshore survey for deer. Mierzwa (pers. comm.) saw a red fox dead on the road on Route 312 east of Cline Avenue on 27 September 1990, and he saw a skull found at Clark and Pine East on 23 April 1991. It is not clear how common this species is in the Grand Calumet River area.

Gray fox, *Urocyon cinereoargenteus* (Schreber).—The gray fox lives in woods and probably inhabits the forests of INDU. Lyon (1923) did not mention this species, but Texas Instruments (1975–80) recorded it on the basis of tracks. Whitaker et al. (1994) reported it at Howe's Prairie on 11 August 1987; and more recently, Dan Fagre saw two east of Dune Acres. The gray fox could occur in the Grand Calumet River region in a wooded area such as in Miller Woods, but its presence is less likely than the red fox because of the scarcity of mature woods.

PROCYONIDAE

Raccoon, *Procyon lotor* Linnaeus.—The raccoon is abundant at INDU and at the Indiana Dunes State Park in campgrounds and other visitor sites. Apparently raccoons were not always so common; Lyon (1923) says "residents state that a few 'coons' are taken each season for their fur. I have no personal knowledge of the animal and I have never been fortunate enough to find foot prints that might have been made by it." Krekeler (1981), Texas Instruments (1975–80), Whitman et al. (1990) and Whitaker et al. (1994) all stated the raccoon was common at INDU; and it should be common in the Grand Calumet River area. Mierzwa et al. (1991) found raccoon tracks at wetland margins during their study.

MUSTELIDAE

Least weasel, *Mustela nivalis* Linnaeus.—The least weasel is a tiny prairie species with a one inch-long tail. Dice (1928) reported the first least weasel from Indiana in Wells County. Lyon (1936) reported this species only from Pulaski and Wells Counties. There is an earlier record for Porter County (Mumford & Whitaker 1982). The specimen is in the Field Museum in Chicago (112538) and was taken by A.L. Rand on 10 June 1950 (Rand & Rand 1951). This species has been taken sparingly throughout the northern three-quarters of Indiana. The first individuals from INDU were collected during the Texas Instruments studies: one from the young foredunes, and one from the black oak/swamp forest. This species favors open fields and feeds heavily upon meadow mice, so foredunes are suitable habitat. The latter habitat is atypical. Another least weasel was killed by a cat on Route 275E, N of U.S. Route 20 in October 1990 (Whitaker et. al. 1994). This species should occur in the Grand Calumet River area.

Long-tailed weasel, *Mustela frenata* Lichtenstein.—This is the most common weasel in Indiana, and it is found throughout the state. It has a much longer tail than the least weasel, which is the only other weasel known in Indiana. Lyon (1923) states, "These animals are fairly common in the region although I have never seen any." He reported that a trapper had taken about 200 individuals in the past three winters in the dunes region but that only two of them were in white pelage. Texas

Instruments (1975–80) did not report this species. Whitman et al. (1990) observed a long-tailed weasel climbing on fallen timber in Miller Woods. Whitaker et al. (1994) took six long-tailed weasels in traps in three habitats and observed tracks of four: one at Howe's Prairie and one in upland forest. This species should be fairly common in the Grand Calumet River area.

Mink, *Mustela vison* Schreber.—The mink is much larger than the long-tailed weasel and has a bushy tail. Lyon (1923) collected a dead mink and said that several minks are trapped each year in the Lakeshore region. Texas Instruments (1975–80) took two from Cowles Bog. One was seen at Dune Acres on 9 January 1988 in a cattail marsh, and an adult and three young were seen along a marsh on Kemil Road in 1990 (Whitaker et al. 1994). The mink should be present in the Grand Calumet River area.

Badger, *Taxidea taxus* Schreber.—Lyon (1923) listed the badger as recently occurring in the Lakeshore region, and Brennan (1923) reported an individual from the Furnessville Blowout. In the fall of 1986, a badger was found near a trash can in a parking lot at INDU (Whitaker et al. 1994). However, its claws had been removed, probably indicating that it had been transported there from some other locality. A badger was found dead in Porter County on Highway 30 about nine miles west of Highway 49, 0.5 mile west of 600 West (at the center of section 23) on 7 September 1990. On two occasions Whitaker et al. (1994) recorded signs that may have been made by badger: tracks in black oak forest at Howe's Prairie on 11 August 1987, and excavations in dry prairie at the proposed campground on 14 July 1987. Larry Reed, a veterinarian at Westchester Animal Clinic, treated a badger captured in the east unit of INDU during 1990. On 9 April 1989, a badger was seen by Mark Harbin and Andrea Halcarz west of the parking lot near the entrance to Dune Acres. It disappeared from view but apparently entered a burrow at the base of a tree on a sandy bank. Badger populations have been increasing in recent years, and these records all indicate that the badger could occur in the area of the Grand Calumet River.

MEPHITIDAE
(skunks)

Striped skunk, *Mephitis mephitis* Schreber.—Lyon (1923) reported skunks as common at INDU and noted that a number were taken each year for fur. Texas Instruments (1975–80) collected two skunks and saw tracks in black oak/swamp forest and in red maple swamp forest. Krekeler (1981) stated that they forage along the beach of Lake Michigan. Whitaker et al. (1994) took two in traps and observed another. It is surprising that none were recorded as roadkill. Skunks surely inhabit the Grand Calumet River basin.

FELIDAE
(cats)

Bobcat, *Felis rufus* Schreber.—The bobcat is exceedingly rare; and it is listed as endangered in Indiana, although individuals keep turning up. The bobcat is recognizable by its short, or "bob" tail, which contrasts with the long tail of the housecat (although an occasional housecat has lost its tail). The latest confirmed records are from Monroe County (1970), Perry County (1975), Jefferson County (1982), Lawrence County (1 record in 1982, 1 in 1994, 2 in 1995, and 1 in 1996), Parke County (1987), Crawford County (1988), Warrick County (1990), Dekalb County (1993), Steuben County (1993) and Washington County (1995). Among numerous unconfirmed reports (most probably erroneous) are two from LaPorte and two from Starke Counties. It is unlikely, but not inconceivable, that the bobcat still exists in wooded areas of the Lakeshore; but it is probably not found in the Grand Calumet River area because of development, lack of forest and habitat fragmentation.

Housecat, *Felis silvestris* Schreber.—Truly feral populations of housecats seldom exist in the eastern United States. Most housecats that forage afield have a house or other building that serves as a home base. There are numerous housecats in the Grand Calumet River area. Housecats are exotics, and as such control might be considered if they become a problem to native animals. To date, there is no indication that the housecat is a problem in the Grand Calumet River area, but it could become one due to the prevalence of buildings nearby.

CERVIDAE
(deer)

White-tailed deer, *Odocoileus virginianus* (Zimmermann).—The white-tailed deer was extirpated from the state before 1900 (Mumford & Whitaker 1982). Re-stocking deer in Indiana began in 1934 when 35 deer were released in seven counties. By 1955 more than 400 deer had been introduced into 22 counties. Population estimates for the state were 900 in 1943, 1200 in 1944, and more than 2900 in 1946. A deer season opened in 1951 when the deer population of the state was estimated at 5000. By 1966, deer were probably present in all counties; and they have continued to multiply, thereby becoming very abundant in recent years.

Texas Instruments (1975–1990), Krekeler (1981) and Whitaker et al. (1994) all indicated that white-tailed deer were common at INDU. Deer were counted by aerial census in 1982, 1984, 1988, 1989, 1991 and 1992. The counts were 85, 29, 214, 349, 166 and 207 deer in those years. The actual populations were larger but it is not known what proportion of the deer was observed, and only about 75% of the Lakeshore was flown. Whitman et al. (1990) saw deer tracks also.

THE HABITATS

At the southern end of Lake Michigan, east of Chicago and east of the Gary/Hammond area, lies the Indiana Dunes National Lakeshore (INDU). Chicago and Gary areas are two of the more highly-developed and heavily-polluted regions of the world. The area was once composed of extensive series of dunes, and classic studies of plant and animal succession were done there (Cowles 1899; Shelford 1912a, b); however, by the middle of the 20th century, the entire area was being developed. Senator Paul Douglas was instrumental in establishing INDU in the area between Gary and Michigan City. Since then, much land has been acquired, many buildings have been razed, and some of the land is being converted to resemble its original condition.

Some of the larger species are not restricted ecologically, but they could occur in any of the terrestrial habitats. Others are more restricted or are characteristic constituents of only a few of the habitats. Some of the mammals with relatively little ecological restriction, at least within an area as small and as varied as the Grand Calumet River basin, are the eastern cottontail, *Sylvilagus floridana*; raccoon, *Procyon lotor*; long-tailed weasel, *Mustela frenata*; striped skunk, *Mephitis mephitis*; and white-tailed deer, *Odocoileus virginiana.*

Mammals likely to be found in the various habitats of the Grand Calumet River basin are listed below separately for each of the habitats. These lists are derived from information in Whitaker et al. (1994), Mierzwa et al. (1991), Mumford & Whitaker (1982), Hoffmeister (1989) and from personal observations (1994).

Agricultural land and old fields.—The plots designated as agricultural areas by Whitaker et al. (1994) in INDU were actually early seral "old fields" rather than cultivated areas, *per se.* Canopy was entirely absent in all of these plots, but scattered shrubs were present in some. The dominant plants were grasses and forbs. In northern Indiana, the meadow vole is the most abundant species in lush meadows, and 90 individuals of this species occurred in the nine plots in this habitat (Whitaker et al. 1994).

Mammal species likely in agricultural fields in the Grand Calumet River basin are the meadow vole, *Microtus pennsylvanicus*; prairie vole, *Microtus ochrogaster*; northern short-tailed shrew, *Blarina brevicauda*; masked shrew, *Sorex cinereus*; meadow jumping mouse, *Zapus hudsonius*; and the eastern mole, *Scalopus aquaticus*

Prairie.—There is a great deal of prairie or grassy oldfield in the Grand Calumet River area with Dry Prairie often grading into or alternating with Wet Prairie.

Dry prairie: The majority of the dry prairie along the Grand Calumet River is on the low dunes between swales or marshes. Dry prairies include a variety of species of grasses and forbs. Cover is often good in this habitat, providing ample hiding spots for small mammals. Marram, sand reed grass or little bluestem dominated most of the plots sampled by Whitaker et al. (1994) at INDU. The little bluestem plots were probably more similar to dry prairie near the Grand Calumet River than the more typical dunes grasses. The dominant small mammal in Dry Prairie at INDU was the prairie deer mouse, *Peromyscus maniculatus*, followed by the white-footed mouse, *Peromyscus leucopus* (Whitaker et al. 1994). Prairie voles occurred, perhaps somewhat surprisingly, in only one of the 11 plots sampled. The generally sparse cover in many of the plots accounts for both the abundance of deer mice and the low number of prairie voles. The prairie deer mouse is the one small mammal of Indiana that is more abundant in areas with less plant growth, and prairie voles thrive only in areas of good plant cover.

Signs observed at INDU in this habitat could have been from the bog lemming, *Synaptomys cooperi.* The thirteen-lined ground squirrel now inhabits primarily mowed areas such as golf courses, lawns, pastures and roadsides. Its occurrence in dry prairies in the dunes might indicate that this habitat was a pre-settlement habitat for this species.

Mammal species likely to be found in dry prairie in the Grand Calumet River basin are the prairie deermouse, *Peromyscus maniculatus bairdii*; white-footed mouse, *Peromyscus leucopus*; prairie vole, *Microtus ochrogaster*; thirteen-lined ground squirrel, *Spermophilus tridecemlineatus*; woodchuck, *Marmota monax*; least shrew, *Cryptotis parva*; Franklin's ground squirrel, *Spermophilus franklinii*; southern bog lemming, *Synaptomys cooperi*; coyote, *Canis latrans*; red fox, *Vulpes vulpes*; least weasel, *Mustela nivalis*; and American badger, *Taxidea taxus.*

Wet prairie: Wet prairie areas contain various grasses and forbs as the dominant plants, and they often contain significant amounts of shrubs such as willow or aspen. Some of the major grasses are *Calamagrostis*, *Panicum*, *Aristida*, *Phalaris*, and *Agrostis.* Cattails and rushes were also dominant in one plot. Cover ranged from fair to excellent.

The most abundant mammal species taken in wet prairie by Whitaker et al. (1994) was the masked shrew. Mumford & Whitaker (1982) earlier (27–28 April 1977) used 1508 snap-traps for two nights and took 60 meadow voles, 22 masked shrews, 16 white-footed mice, and ten short-tailed shrews. Most of the traps were in grass sedge meadow, which included clumps of willows. The voles were feeding extensively on the willow fruits. The fruiting twigs were 0.5–1.0 m high, and the voles were getting the fruiting heads by cutting off the twigs, pulling them down, and recutting them until the heads were reached, leaving cuttings 4–15 cm long in piles with the fruiting leaflets and parts of the fruits on top of the piles of twigs. The stomachs of the mice were full of this material.

Mammal species likely to be found in wet prairie in the Grand Calumet River basin: meadow vole, *Microtus pennsylvanicus*; masked shrew, *Sorex cinereus*; northern short-tailed shrew, *Blarina brevicauda*; white-footed mouse, *Peromyscus leucopus*; meadow jumping mouse, *Zapus hudsonius*; and the southern bog lemming, *Synaptomys cooperi.*

Lowland terrestrial shrub.—There is a fair amount of terrestrial shrubland in the area of the Grand Calumet River. Shrubby species expected might be willow, aspen, red maple, or red ozier dogwood (*Cornus stolonifera*), and a variety of grasses and forbs are likely. No species of mammal was dominant or even abundant in the lowland terrestrial shrubland. The white-footed mouse was the most abundant mammal, but only six individuals were taken.

Mammal species likely in lowland terrestrial shrubland in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus) and eastern cottontail (Sylvilagus floridanus.*

Upland terrestrial shrub.—There is a fair amount of upland terrestrial shrubland in the area of the Grand Calumet River. Four plots sampled by Whitaker et al. (1994) in upland terrestrial shrubland all were in highly disturbed transition stages between grassy oldfield or savanna and wooded habitats. One plot was highly productive, yielding 44 individuals of four mammal species. The nine shrews and 33 meadow voles taken there clearly reflected the former field habitat rather than the present transitional shrub stage, and these forms will undoubtedly disappear from this area as the transition toward more woody vegetation continues in this plot. A total of 14 species (including the domestic dog) was found in this habitat, but most were in low numbers. The author suspects that the lack of a well-developed community in shrubland is due to the ephemeral nature of the habitat.

Mammals likely in upland terrestrial shrubland in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), eastern cottontail (*Sylvilagus floridanus*), and white-tailed deer (*Odocoileus virginiana*).

Oak savanna.—Oak savanna is a common habitat in the Grand Calumet River basin, and 15 oak savanna plots were studied by Whitaker et al. (1994) at the Lakeshore. All had a canopy of nearly pure black oak, usually thin.

Table 2.—Likely mammal species of Calumet basin, pre-settlement, present, and likely origin (native, reintroduced native, introduced exotic, extirpated).

Native mammals, probably present in pre-settlement times, but gone now.	Pre-settlement	Now	Status
Rodentia			
Erethizon dorsatum, American porcupine	yes	no	native
Carnivora			
Canis lupus, gray wolf	yes	no	native
Ursus americanus, black bear	yes	no	native
Martes pennanti, fisher	yes	no	native
Lutra canadensis, river otter	yes	no	native
Felis concolor, mountain lion	yes	no	native
Felis lynx, Canada lynx	yes	no	native
Felis rufus, bobcat	yes	no	native
Artiodactyla			
Cervus canadensis, American elk	yes	no	native
Bos bison, American bison	yes	no	native
Native mammals present in pre-settlement times, extirpated by 1900, then reintroduced.			
Castor canadensis, American beaver	yes	yes	reintrod.
Odocoileus virginiana, white-tailed deer	yes	yes	native
Native mammals probably present in pre-settlement times to present.			
Marsupialia—Marsupials			
Didelphis virginiana, Virginia opossum	yes	yes	native
Insectivores—Shrews and Moles			
Scalopus aquaticus, common mole	yes	yes	native
Cryptotis parva, least shrew	yes	yes	native
Blarina brevicauda, northern short-tailed shrew	yes	yes	native
Sorex cinereus, masked shrew	yes	yes	native
Chiroptera—Bats			
Myotis lucifugus, little brown myotis	yes	yes	native
Lasiurus borealis, eastern red bat	yes	yes	native
Lasionycteris noctivagans, silver-haired bat	yes	yes	native
Eptesicus fuscus, big brown bat	yes	yes	native
Lagomorpha—Rabbits and Hares			
Sylvilagus floridana, eastern cottontail	yes	yes	native

Table 2.—Continued.

Native mammals, probably present in pre-settlement times, but gone now.	Pre-settlement	Now	Status
Rodentia—Rodents			
Tamias striatus, eastern chipmunk	yes	yes	native
Marmota monax, woodchuck	yes	yes	native
Spermophilus franklinii, Franklin's ground squirrel	yes	yes	native
Spermophilus tridecemlineatus, thirteen-lined ground squirrel	yes	yes	native
Sciurus carolinensis, gray squirrel	yes	yes	native
Sciurus niger, fox squirrel	yes	yes	native
Tamiasciurus hudsonicus, red squirrel	yes	yes	native
Glaucomys volans, southern flying squirrel	yes	yes	native
Peromyscus leucopus, white-footed mouse	yes	yes	native
Peromyscus maniculatus bairdii, prairie deermouse	yes	yes	native
Microtus ochrogaster, prairie vole	yes	yes	native
Microtus pennsylvanicus, meadow vole	yes	yes	native
Microtus pinetorum, pine vole	yes	yes	native
Ondatra zibethicus, common muskrat	yes	yes	native
Synaptomys cooperi, southern bog lemming	yes	yes	native
Zapus hudsonius, meadow jumping mouse	yes	yes	native
Carnivora			
Canis latrans, coyote	yes	yes	native
Vulpes vulpes, red fox	yes	yes	native
Urocyon cinereoargenteus, gray fox	yes	yes	native
Procyon lotor, raccoon	yes	yes	native
Mustela nivalis, least weasel	yes	yes	native
Mustela frenata, New York weasel	yes	yes	native
Mustela vison, mink	yes	yes	native
Taxidea taxus, American badger	yes	yes	native
Mephitis mephitis, striped skunk	yes	yes	native
Introduced exotics			
Rattus norvegicus, Norway rat	no	yes	exotic
Mus musculus, house mouse	no	yes	exotic

Both the shrub and herb layer varied considerably. Some of the more abundant shrubs were blackberry, blueberry, rose and Japanese honeysuckle. Abundant herbaceous plants were *Andropogon*, *Panicum*, *Carex*, goldenrod and bracken fern. Thirty white-footed mice and 18 prairie deer mice were taken, although the prairie deer mice occurred in only three of the plots. These are the results one would expect since the prairie deer mouse favors sparsely vegetated, dry areas without woody vegetation. The white-footed mouse is a species of the woods, and savanna is a thinly wooded habitat.

Mammal species likely in oak savanna in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), prairie white-footed mouse (*Peromyscus maniculatus bairdii*), prairie vole (*Microtus ochrogaster*), eastern cottontail (*Sylvilagus floridanus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), Franklin's ground squirrel (*Spermophilus franklinii*), and eastern mole (*Scalopus aquaticus*).

Mixed deciduous savanna.—Three plots in mixed deciduous savanna at the Lakeshore all had scattered cottonwoods with little bluestem as the principal herbaceous species (Whitaker et al. 1994). Major grasses in this habitat were old little bluestem, old witch grass and brome grass; and grape and aromatic sumac were among the more abundant shrubs. Cover was fair-to-good in these plots due to the grass. The white-footed mouse was the most abundant mammal, being taken at all three plots with a total of 20 individuals.

Mammal species likely in mixed deciduous savanna in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), prairie white-footed mouse (*Peromyscus maniculatus bairdii*), prairie vole (*Microtus ochrogaster*), eastern cottontail (*Sylvilagus floridanus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), Franklin's ground squirrel (*Spermophilus franklinii*), and eastern mole (*Scalopus aquaticus*).

Upland forest.—Upland forest, mostly oak, is widespread at INDU (Whitaker et. al. 1994). There is relatively little mature forest in the Grand Calumet River basin, but scrubby black oaks in much of the forest in the Grand Calumet River basin grade into scrubby black oak savanna. The shrub layer at INDU was often dense and diverse in this habitat, but it often contained blueberry (*Vaccinium vacillans*). The herbaceous layer was again diverse, although often thin and depauperate, most often providing poor-to-fair cover. The dominant herbaceous plants there were most often Pennsylvania sedge (*Carex pennsylvanicus*) and bracken fern (*Pteridium aquilinum*). The white-footed mouse was the most abundant small mammal in upland oak forest.

Mammal species likely to be found in upland forest in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), eastern chipmunk (*Tamias striatus*), southern flying squirrel (*Glaucomys volans*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*Sciurus niger*), raccoon (*Procyon lotor*), red squirrel (*Tamiasciurus hudsonicus*), northern short-tailed shrew (*Blarina brevicauda*), pine vole (*Microtus pinetorum*) and gray fox (*Urocyon cinereoargenteus*).

Lowland forest.—Lowland forest was divided into perennial (contains water more than six months of the year) and ephemeral wet lowland forest and was the second largest habitat after upland forest in INDU (Whitaker et al. 1994). The canopy was usually quite dense but varied in species composition. Common trees were silver or red maple followed by oak, ash, aspen, elm and sassafras. The shrub layer varied from sparse to dense; and it consisted mostly of seedlings of the trees mentioned above plus spicebush, *Viburnum*, *Cornus*, *Ilex*, *Rubus*, blueberries and others. Ground cover varied from fair to excellent; and species composition varied greatly between plots, with graminoid plants ferns being common. The herb and shrub layers were often clumped in hummocks. As usual in wooded habitats, the white-footed mouse was the most abundant species taken, totaling 137 in 27 plots (Whitaker et al. 1994).

Mammal species likely to be found in lowland forest in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), raccoon (*Procyon lotor*), northern short-tailed shrew (*Blarina brevicauda*), opossum (*Didelphis virginiana*), gray fox (*Urocyon cinereoargenteus*) and Eastern chipmunk (*Tamias striatus*).

Wetlands.—There is a variety of types of wetlands at INDU and also in the Grand Calumet River basin, marsh, aquatic shrubland, swamp, panne (depressions among the dunes) and open water.

Marsh: Marsh is prominent at INDU and in the Grand Calumet River basin. The herb layer was most often of cattail (*Typha*), sedges (*Carex*), bulrushes (*Scirpus*) or blue joint grass (*Calamagrostis canadensis*). The canopy was absent in most areas but consisted of scattered willows or elms in a few. The shrub layer consisted of thick buttonbush (*Cephalanthus occidentalis*) in most of the plots, whereas willow was present in one. Muskrats are abundant in many of the marshes, lakes and ditches of INDU, and would be in the basin if the water were clean.

Mammal species likely to be found in marshes in the Grand Calumet River basin are the muskrat (*Ondatra zibethicus*), white-footed mouse (*Peromyscus leucopus*), masked shrew (*Sorex cinereus*), meadow vole (*Microtus pennsylvanicus*), raccoon (*Procyon lotor*) and short-tailed shrew (*Blarina brevicauda*).

Aquatic shrublands: Aquatic shrublands made up a small but significant part of INDU and likewise also of the Grand Calumet River basin. Vegetation was of aspens, willows or oaks; and the herb layer was of blue joint grass, reed grass or cattails.

Mammal species likely in aquatic shrublands in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*) and raccoon (*Procyon lotor*).

Swamp: In the plots in swamp at INDU, (Whitaker et. al. 1994), the canopy was cottonwood and/or black willow (*Salix nigra*). The ground cover was excellent in each case, and it mainly consisted of grasses (blue joint grass or *Phalaris*), sedges (*Carex*) and cattails (*Typha*). Additional collections were made by Whitaker and R.E. Mumford in the fall of 1978 in the swamp just north of Cowles Bog. Three species were taken there, including 33 masked shrews, two short-tailed shrews, and 10 white-footed mice.

Mammal species likely to be found in swamp in the Grand Calumet River basin are the white-footed mouse (*Peromyscus leucopus*), masked shrew (*Sorex cinereus*) and raccoon (*Procyon lotor*).

Pannes: The pannes are shallow depressions among the dunes. They contain water much of the time and are often surrounded by grassy areas and shrubs. The canopy layer is usually absent. Shrub growth is often dense and consists of various species such as red ozier dogwood, willow and St. John's wort (*Hypericum kalmianum*). The herb layer usually forms good cover. A number of herbaceous species were present, including several members of the family Cyperaceae, *Eleocharis*, *Cladium*, *Rhynchospora*, a rush (*Juncus balticus*), strawberry, mountain mint (*Pycnanthemum virginianum*) and others. Five species of mammals were taken by Whitaker et al. (1994) in the three plots in pannes in INDU. The meadow vole was the only regularly occurring species with 13 being taken in two of the three plots. Three white-footed mice were taken in one of the plots, and three prairie deer mice were taken in another.

Mammal species likely to be found in pannes in the Grand Calumet River basin are the meadow vole (*Microtus pennsylvanicus*), white-footed mouse (*Peromyscus leucopus*) and prairie vole (*Microtus pennsylvanicus*).

Artificial habitats.—Various artificial habitats or developed lands including croplands, residential and industrial areas, right-of-ways and excavated areas are found at INDU and also in the Grand Calumet River basin.

Right-of-ways: Right-of-ways occur along roads, railroads or trails. However, they do not form a distinct habitat. Instead, they pass through and consist of some other habitat such as mature woods, dry prairie, etc. Therefore, many different plants are present, including several grasses and rushes, and several other plant species (*Melilotus*, *Saponaria*, *Solidago*, *Clematis*, *Dryopteris thelypterus*, *Carex*, *Typha*) as dominants in at least one plot. Because of the high variation in these plots, no list of expected species of mammals is given.

Excavated areas: Excavated areas are places of open sand due to human activities. There are three plots in this habitat at INDU (Whitaker et al. 1994), and there are areas with this habitat due to sand-mining in the Grand Calumet River watershed. One of the INDU plots is on the site of a former fly ash seepage area and another is on the site of a steel company acid spill. All three plots completely lack canopy, and two have poor ground cover, with scattered grasses, including little bluestem, sand reed grass and nodding wild rye (*Elymus canadensis*). The third plot has excellent cover of Joe-pye weed (*Eupatorium serotinum*), bullrush (*Scirpus cyper-*

inus) and spikerush (*Eleocharis* sp.). Only two mammals were trapped in plots in this habitat: a meadow vole and a raccoon. As expected, it is not a good habitat for mammals, although mammals do pass through these areas.

RESTORATION POSSIBILITIES

Acquisition of land.—The Grand Calumet watershed, like INDU, was made into an ecological showpiece under the leadership of Senator Paul Douglas. It has been greatly developed and has significant ecological problems. Perhaps efforts could be made under public ownership to obtain parts of the Grand Calumet watershed. It could then be reverted to the original habitat as much as possible.

Fragmentation.—One of the major problems for the Grand Calumet watershed is fragmentation. This has several implications; but most importantly, it inhibits organism dispersal. The fragments of habitat are often separated by areas difficult or impossible for animals (or plants) to bridge. This confines the animals within smaller tracts of land. Under normal circumstances, when populations are eliminated from a patch of habitat, more individuals move in and re-populate. With increased fragmentation, patches of habitat are often not re-populated because there is no available source of emigrants. Fragmentation can also result in inbreeding, due to the lack of new genetic material. Finally, organisms that disperse often die when they are unable to locate suitable habitat after they leave their birthplace.

There are other disadvantages of fragmentation. Fragmentation may allow other animals to penetrate and compete with animals normally found there. An example of this is the cowbird, which penetrates fragmented forests and lays its eggs in nests of other birds.

Attempts could be made to preserve large tracts of habitat in the Grand Calumet basin, especially marsh, dry prairie, wet prairie and mature woodland. Also, special efforts could be made to obtain or to create additional similar habitat between the tracts to allow dispersal. There is little mature forest remaining in the Grand Calumet basin, so its preservation is important.

Endangered/threatened species.—Only one endangered or threatened species of mammal, Franklin's ground squirrel, is known to inhabit the Grand Calumet River area. Two individuals were found by Mierzwa et al. (1991). Both animals were in the dunes between swales. Special efforts might be made to preserve or to create as much dry prairie as possible to help increase populations of this species.

The only other threatened or endangered mammal species likely to occur in the Grand Calumet River basin is the Indiana myotis. This species has not been taken there, but with enough mature wooded habitat, it could survive there. Dry prairie needs to be preserved in the Grand Calumet watershed in an effort to induce populations of Franklin's ground squirrels to live and thrive there.

Efforts could also be made to find and preserve mature woods, especially in the vicinity of Miller Woods, in order to produce as much contiguous mature woodland as possible. This would help all bat species as well as other woodland species.

Exotics.—Exotic plants and animals often compete with and sometimes supplant native species. Therefore, we often wish to eliminate them. There are two exotic mammals in the Grand Calumet River area: the house mouse (*Mus musculus*) and the Norway rat (*Rattus norvegicus*). However, both are uncommon in habitats like those in the Grand Calumet River basin, and efforts to increase natural habitat would help to control them further. Producing and maintaining native habitat would help control these exotic species.

Reintroduction of species.—In order to restore previous habitats and communities, reintroduction could be considered for species previously existing in the Grand Calumet River basin. However, many introductions would not be currently feasible. Species not previously present might not fit into local habitats, so their introductions would not be logical. Each of the ten extirpated species of mammals was considered for possible reintroduction. Because of their size and the present developed state of the area, the following species would be completely impractical for reintroduction at this time: timber wolf, black bear, mountain lion, Canada lynx, bison and American elk. The other four are discussed below.

Porcupine: This species needs extensive woodland to survive, and attempts could be possibly be made to restore it to INDU. This effort would require public education, as many people have an aversion or bias towards this species (as towards snakes and bats). Since extensive woodland is required by this species, it could not be reintroduced into the Grand Calumet watershed in the near future, except perhaps in the Miller Woods area.

River otter: The river otter can live well alongside humans, and it is currently being reintroduced into Indiana. It requires extensive, relatively unpolluted aquatic habitat (ponds, lakes or rivers). If the Grand Calumet River could be cleaned up and protected, the river otter could be considered for reintroduction.

Bobcat: The bobcat was thought to be nearly extirpated in Indiana, but it is showing up in various counties. There is some evidence that it occurs at INDU. This species can live in fairly close proximity to humans, but it does need rather extensive natural woodland habitat because it moves about considerably. The lack of existing woodland in the Grand Calumet basin does not favor its reintroduction.

Areas of special interest.—There are several areas of ecological interest in the Grand Calumet River Basin (such as Roxanna marsh, DuPont wetlands, and the Grand Calumet Lagoons) because of their high quality habitat for semi-aquatic mammals. To reduce fragmentation, as many areas between these high quality areas, could be purchased or otherwise protected.

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BIRDS OF THE GRAND CALUMET RIVER BASIN

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ABSTRACT. Bird life in the Grand Calumet River Basin is unusually rich. The literature reveals that a minimum of 163 species was recorded in the pre-settlement era. Current data document that the basin hosts at least 41 species in winter, 64 species during the breeding season, and more than 167 migrants. Four of the breeding period species and four of the recorded migrants are on the Indiana Endangered Species list. Roxanna Pond, which lies within a Grand Calumet River meander near Roxanna Street, provides excellent habitat for migrating shorebirds and possesses the potential for development into a shorebird management site.

Keywords: Birds, Grand Calumet River, Indiana

Birdlife, and especially breeding birds, constitutes a very sensitive environmental barometer. Therefore, it is surprising that, despite years of abuse, the Grand Calumet River Basin still supports a remarkably diverse avifauna. In recent decades, the sluggish channel and lush wetlands of the river's floodplain have provided breeding habitat, resting areas, and foraging sites for numerous birds. Contemporary records suggest that at least 64 species either nest or forage on the river floodplain during the breeding season. Four of these species, the American Bittern, Least Bittern, Black-crowned Night-Heron, and Black Tern, are listed among Indiana's endangered species (Buskirk 1993). More than 167 species use the channel, ponds, and wetlands of the river corridor for resting and feeding during migration. Four of these migrants, the Osprey, Northern Harrier, Peregrine Falcon, and Golden-winged Warbler, are on Indiana's endangered species list. The open waters of the channel provide winter habitat for at least 41 avian species.

Data from the pre-settlement era are sparse, but they suggest the following minimum counts: 32 species were summer residents, 126 species were migrants, and 15 species were winter residents. These estimates are extremely conservative, since the pre-settlement Grand Calumet River Basin surely supported an exceedingly luxuriant selection of avian habitats.

Our current knowledge about the birdlife of the Grand Calumet River Basin, including pre-settlement data, is summarized in this paper. Species names and phylogenetic arrangement follow the 6th Edition of the *American Ornithologists' Union Checklist* (1983) and subsequent supplements.

PRE-SETTLEMENT BIRD LIFE

The primary historical data sources available are Butler (1898), Woodruff (1907), and Ford et al. (1934). For the most part, historical evidence of pre-settlement birdlife is circumstantial. Of the birds known to have nested in northwestern Indiana or the Chicago region, only those that would frequent Grand Calumet River habitats are considered part of the river's avifauna. When available, however, specific references to the birds of the Grand Calumet River Basin are cited. Pre-settlement avian communities were almost certainly far richer in species composition than is indicated by the following list.

Pre-Settlement Summer Residents

Pied-billed Grebe (***Podilymbus podiceps***).—Butler (1898) states that this species is present throughout the greater part of Indiana. Pied-billed Grebes almost certainly nested in the wetlands along the Grand Calumet River.

Horned Grebe (***Podiceps auritus***).—This species probably never nested in the marshes along the Grand Calumet River; however, Woodruff (1907) reported that a downy juvenile was collected on 24 May 1878 at Sheffield (now part of Hammond). West (1956) questioned the validity of this report.

American Bittern (*Botaurus lentiginosus*).—Butler (1898) noted that this species was a summer resident at suitable localities, especially in northern Indiana. In addition, Ford et al. (1934) state that numerous breeding records are available for the Chicago area. *Botaurus lentiginosus* probably nested in the cattail marshes on the Grand Calumet River floodplain.

Least Bittern (*Ixobrychus exilis*).—According to Butler (1898), the Least Bittern was a summer resident at suitable localities, which almost certainly included the wetlands along the river.

Great Blue Heron (*Ardea herodias*).—Several authors, including Butler (1898), suggest that the Great Blue Heron was a common nesting species across the northern half of Indiana. No evidence for local nesting exists, but *A. herodias* almost certainly occupied the Grand Calumet River floodplain during its late summer dispersal.

Green Heron (*Butorides striatus*).—Both Butler (1898) and Woodruff (1907) list this species as a common summer resident. The Green Heron very likely inhabited scrubby trees along the river.

Black-crowned Night Heron (*Nycticorax nycticorax*).—Woodruff (1907) quotes the following statement by E.W. Nelson: "The first of July, 1874, I saw a few young of the year in the Calumet Marshes." Birds present at this date could represent either locally fledged individuals or post-nesting dispersals from colonies outside the Grand Calumet River Basin.

Mallard (*Anas platyrhynchos*).—Butler (1898) suggests that this species was a permanent resident in Indiana. The Mallard probably nested on the floodplain.

Blue-winged Teal (*Anas discors*).—Butler (1898) referred to this small duck as a local summer resident. The Blue-winged Teal very likely nested in wetlands on the Grand Calumet River floodplain.

Northern Shoveler (*Anas clypeata*).—Mumford & Keller (1984) state that Butler (no reference or date given) reported nesting in Lake County. The wetlands along the Grand Calumet River would have included appropriate nesting habitat for this dabbler.

Ruddy Duck (*Oxyura jamaicensis*).—Without specifying the exact locations, Mumford & Keller (1984) state that *O. jamaicensis* nested in Lake County in 1953, 1959, 1961, 1962, and 1965. Historical nestings probably occurred along the Grand Calumet River.

King Rail (*Rallus elegans*).—During the 19th Century, this species was a summer resident north of the Wabash Valley (Butler 1898). King Rails almost certainly the occupied marshes on the Grand Calumet River floodplain.

Virginia Rail (*Rallus limicola*).—Butler (1898) referred to Virginia Rails as local summer residents, principally in northern Indiana. This rail undoubtedly nested in the wetlands along the Grand Calumet River.

Sora (*Porzana carolina*).—According to Butler (1898), the Sora was a common breeder in northern Indiana.

Common Moorhen (*Gallinula chloropus*).—*Gallinula chloropus*, a summer resident that breeds in the more extensive swamps (Butler 1898), almost certainly nested in the wetlands along the Grand Calumet River.

American Coot (*Fulica americana*).—Butler (1898) deemed *F. americana* to be a common summer resident in northern Indiana.

Wilson's Phalarope (*Phalaropus tricolor*).—According to Butler (1898), *P. tricolor* was a common breeding species in extreme northwestern Indiana. The last recorded nesting was in 1941 (Mumford & Keller 1984).

Black Tern (*Chlidonias niger*).—Black Terns were summer residents in the marshes north of the Kankakee River; they bred commonly at some locations (Butler 1898). Mumford & Keller (1984) indicate that 40 nests were found near Wolf Lake in 1924, making it highly likely that some nested within the Grand Calumet River Basin.

Marsh Wren (*Cistothorus palustris*).—Butler (1898) referred to this species as an abundant resident of Indiana's marshes. *Cistothorus palustris* surely nested at every site that provided the requisite cattail stands.

Gray Catbird (*Dumetella carolinensis*).—Woodruff (1907) deemed *D. carolinensis* to be an abundant summer resident in the Chicago region. The catbird probably nested in dense shrubbery on the river's floodplain.

Cedar Waxwing (*Bombycilla cedrorum*).—A common summer resident in the Chicago region (Woodruff 1907), *Bombycilla cedrorum* very likely foraged, and perhaps nested, on the Grand Calumet River floodplain.

Yellow Warbler (*Dendroica petechia*).—This species was an abundant summer resident of the Chicago region (Butler 1898). Undoubtedly, *D. petechia* nested along the Grand Calumet River.

Common Yellowthroat (*Geothlypis trichas*).—Butler (1898) referred to this species as a common summer resident of the Chicago region. The Common Yellowthroat almost certainly nested in cattail marshes on the Grand Calumet River floodplain.

Indigo Bunting (*Passerina cyanea*).—According to Woodruff (1907), *P. cyanea* was a common summer resident in the Chicago region, and this species probably nested in scrubby trees on the river's floodplain.

Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*).—Woodruff (1907) quotes Nelson: "The 12th of June, 1875, I saw several of these birds in the dense grass bordering Lake Calumet, where they were undoubtedly breeding." Although Lake Calumet is slightly outside the study area, this report raises the intriguing possibility of historical nestings along the Grand Calumet River. No modern evidence exists to support the belief that the Sharp-tailed Sparrow breeds anywhere in the Chicago region.

Song Sparrow (*Melospiza melodia*).—Butler (1898) characterized *M. melodia* as a permanent Chicago area resident; no doubt a few individuals nested in scrubby habitat on the floodplain.

Swamp Sparrow (*Melospiza georgiana*).—Woodruff (1907) deemed this species to be a common summer resident of the Chicago region, where it almost certainly nested in the floodplain marshes.

Red-winged Blackbird (*Agelaius phoeniceus*).—This widespread and common species (deemed to be an abundant summer resident by Butler (1898)), almost certainly nested in the cattail marshes along the river.

Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*).—According to Butler (1898), *X. xanthocephalus* was a summer resident at some localities in northwestern Indiana. This species probably inhabited some of the cattail marshes along the Grand Calumet River.

Common Grackle (*Quiscalus quiscula*).—Butler (1898) considered *Q. quiscula* a common summer resident; the birds probably foraged on the river's floodplain.

Brown-headed Cowbird (*Molothrus ater*).—According to Butler (1898), *M. ater* was a common summer resident in Indiana. This species was undoubtedly present on the floodplain.

American Goldfinch (*Carduelis tristis*).—This species, deemed to be a permanent resident of the Chicago region by Butler (1898), almost certainly bred in the Grand Calumet River marshes.

Pre-Settlement Migrants

The elongate geometry of Lake Michigan imposes a major geographical limit on southbound migrants, directing thousands to the southern tip of Lake Michigan and across the Grand Calumet River (Brock 1986). Untold numbers surely passed over the Grand Calumet River during pre-settlement migrations. Those species preferring habitats provided by the river floodplain probably stopped to feed and rest. The literature provides little firsthand evidence as to what migratory species were actually observed on the Grand Calumet River; indeed, specific references were available for only two species.

Osprey (*Pandion haliaetus*).—Woodruff (1907) reports seeing migrants on both Lake Calumet and Berry Lake. Osprey probably hunted over the waters of the Grand Calumet River.

Le Conte's Sparrow (*Ammodramus leconteii*).—Woodruff (1907) quotes E.W. Nelson, who refers to a specimen collected in May 1875: ". . . The specimen in my possession was flushed from a small depression in the prairie near the Calumet River [in Illinois] . . ."

Species known to migrate through the Chicago region, whose habitat preferences included the types provided by the Grand Calumet River, are listed in Table 1.

CURRENT BIRD LIFE

Data Sources

Information included below concerning the current avifauna in the Grand Calumet River Basin is drawn from recent publications and from unpublished field data. Contemporary literature sources include Brock (1986), Mumford & Keller (1984), Mierzwa et al. (1991), and Mlodinow (1984). Unpublished field data include observations made by the author and various other competent observers. Unless ex-

Table 1.—Pre-settlement winter residents. The following species include those birds known to nest in the Chicago area (Woodruff 1907) or in northwestern Indiana (Butler 1898) that probably wintered in the wates or marshes of the Grand Calumet River.

Common name	Genus and species
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Bufflehead	*Bucephala albeola*
Red-breasted Merganser	*Mergus serrator*
American Coot	*Fulica americana*
American Crow	*Corvus brachyrhynchos*
Cedar Waxwing	*Bombycilla cedrorum*
Northern Shrike	*Lanius excubitor*
American Tree Sparrow	*Spizella arborea*
Dark-eyed Junco	*Junco hyemalis*
Red-winged Blackbird	*Agelaius phoeniceus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Common Redpoll	*Carduelis flammea*
American Goldfinch	*Carduelis ristis*

plicitly stated in the text, the observation was made by the author. These data, which include more than 100,000 individual records, are stored in computer files accessible by personal computer.

Field data are not distributed uniformly along the river; a disproportionate fraction of the reports are concentrated at easily accessible sites. The most thoroughly sampled locations, in order of descending importance, are the Roxanna Marsh, Hammond Sanitary District, Lagoons, DuPont, and Gary Sanitary District Reaches (Table 3).

Modern data reveal that the watershed supports an unusually rich avifauna. The wetlands provide breeding or summer foraging habitat for at least 64 species, including several that are on Indiana's endangered and threatened species lists. In addition, the floodplain serves as a resting and feeding area for numerous migrants. Indeed, the greatest avian diversity is seen during periods of migration.

Considerable species diversity is obvious in the monthly data collected at the DuPont property by Mierzwa et al. 1991 (fig. 1). The maximum number of species occurs during the May and August migration peaks, and the winter months have the lowest diversity.

Table 2.—Winter resident bird species in the Grand Calumet River corridor. Those species marked with an asterisk (*) are rare (not present in most years).

Common name	Genus and species
*Pied-billed Grebe	*Podilymbus podiceps*
*Double-crested Cormorant	*Phalacrocorax auritus*
*Great Blue Heron	*Ardea herodias*
*Black-crowned Night Heron	*Nycticorax nycticorax*
Canada Goose	*Branta canadensis*
*Green-winged Teal	*Anas crecca*
American black duck	*Anas rubripes*
Mallard	*Anas platyrhynchos*
*Northern Shoveler	*Anas clypeata*
*Redhead	*Aythya americana*
Common Goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
*Hooded Merganser	*Lophodytes cucullatus*
Common Merganser	*Mergus Merganser*
Red-breasted Merganser	*Mergus serrator*
Ring-necked Pheasant	*Phasianus colchicus*
*Common Moorhen	*Gallinula chloropus*
American Coot	*Fulica americana*
Ring-billed Gull	*Larus delawarensis*
Hering Gull	*Larus argentatus*
Glaucous Gull	*Larus hyperboreus*
Rock Dove	*Columba livia*
Mourning Dove	*Zenaida macroura*
Belted Kingfisher	*Ceryle alcyon*
Downy Woodpecker	*Picoides pubescens*
Blue Jay	*Cyanocitta cristata*
American Crow	*Corvus brachyrhynchos*
Cedar Waxwing	*Bombycilla cedrorum*
European Starling	*Sturnus vulgaris*
Northern Cardinal	*Cardinalis cardinalis*
American Tree sparrow	*Spizella arborea*
*Fox Sparrow	*Passerella iliaca*
Song Sparrow	*Melospiza melodia*
Swamp Sparrow	*Melospiza georgiana*
Dark-eyed Junco	*Junco hyemalis*
Red-winged Blackbird	*Agelaius phoeniceus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
House Finch	*Carpodacus mexicanus*
*Common Repoll	*Carduelis flammea*
American Goldfinch	*Carduelis tristis*

Contemporary Breeding Species and Summer Residents

Habitat availability and quality are the most critical factors for breeding birds. The typical avian habitats in the Grand Calumet River Basin include sluggish perennial streams, ponds, cattail marshes, lakes, artificial ponds, and marshes infested with exotic plant species. Several of these provide important breeding habitat for many species on Indiana's list of endangered and threatened species. Many wetland breeding species have successfully adapted to cattail marshes, but none appear to have adapted to habitats infested with common reed and purple loosestrife, two common exotics.

Current data indicate that 63 species occupy the Grand Calumet River floodplain during the summer breeding season (June and July). Recent changes in the river's bird population include a significant increase in non-breeding herons and egrets. In addition, a substantial decrease in nesting by Common Moorhens and American Coots was noted during the 1990's. Two species, the Black Tern and Yellow-headed Blackbird, have been extirpated as breeding species in the Grand Calumet River Basin. Data not cited in the following accounts were taken from Mierzwa et al. 1991.

Pied-billed Grebe (*Podilymbus podiceps*).—This grebe is a common summer resident on the channel; the species is seen regularly from late April through early October but is most frequently reported in July and August. The observation of three juveniles at Roxanna Pond in August 1984 and five young at Bongi Pond in June 1991 confirms local breeding.

American Bittern (*Botaurus lentiginosus*).—This Indiana-endangered species has virtually disappeared as a breeding species from Indiana. The only summer record for the watershed consists of a single bird flushed from the cattail marshes on the DuPont property on 11 July 1991.

Least Bittern (*Ixobrychus exilis*).—*Ixobrychus exilis*, an Indiana-endangered species, is a rare summer resident of the cattail marshes on the river's floodplain. The species was seen at Roxanna Pond in August 1983, and at least two adults were found at that location in July 1984 (seen by author). The most recent summer reports were made in the DuPont wetlands, where one or two pairs were present throughout the summer in 1991.

Great Blue Heron (*Ardea herodias*).—Though evidence of nesting is lacking, foraging birds are seen regularly along muddy banks of the channel and especially at Roxanna Pond. During 1996, this species nested on the nearby Little Calumet River floodplain in Lake County (Brock pers. obs.).

Great Egret (*Ardea albus*).—Over the last decade, observations of this species have increased dramatically, paralleling the establishment of a nesting colony at nearby Lake Calumet, Illinois. This expansion is especially encouraging because *A. albus* is currently on Indiana's "species of special concern" list. Today, birds are frequently observed feeding along the channel and especially at Roxanna Pond. During June and July at Roxanna Pond, a mean of 9.3 birds per year was recorded over the past 12 years; the peak count was 30 on 15 June 1996. No evidence of nesting is available for the Grand Calumet River floodplain; presumably, the summer birds represent either foraging individuals from the Illinois colony or non-breeding wanderers.

Green Heron (*Butorides striatus*).—During the summer, small numbers of *B. striatus* are seen regularly along the channel. A peak count of three was recorded at Roxanna Pond on 3 July 1985. Though nesting has not been confirmed, this species probably breeds sparingly in scrubby trees along the channel.

Black-crowned Night Heron (*Nycticorax nycticorax*).—Currently on Indiana's endangered species list, *N. nycticorax* is a common summer visitor to the Grand Calumet River floodplain. At Roxanna Pond, a mean of 5.5 birds per year was observed during June and July over the past dozen years. The 11 birds counted at Roxanna Pond on 8 July 1986 were probably post-nesting dispersals from the Lake Calumet rookery in Illinois. Evidence of local nesting is lacking; most of the birds observed are presumed to be foraging birds from the Lake Calumet colony.

Canada Goose (*Branta canadensis*).—This species is an abundant summer resident that frequently nests on the floodplain.

Wood Duck (*Aix sponsa*).—*Aix sponsa* is seen regularly on the channel during the summer. The species may occasionally nests in the watershed; two young birds were observed at Roxanna Pond on 1 June 1985. A peak summer count of 12 was seen on 5 June 1987.

Mallard (*Anas platyrhynchos*).—Substantial numbers of Mallards can be seen in the channel of the Grand Calumet River during the summer. The peak summer count was 60 at Roxanna Pond on 10 July 1982. Counts of downy young at Roxanna Pond include seven

Table 3.—The following species are migrants through the Grand Calumet River Basin. The Indiana status of each of these migrants is defined according to Buskirk (1993): en = endangered; th = threatened; sc = special concern; and ex = extirpated as a breeding species.

Common name	Species name	Historical	Modern	Status
Red-throated Loon	*Gavia stellata*		●	
Common Loon	*Gavia immer*		●	
Pied-billed Grebe	*Podilymbus podiceps*	●	●	
Horned Grebe	*Podiceps auritus*		●	
Red-necked Grebe	*Podiceps grisegena*		●	
Eared Grebe	*Podiceps nigricollis*		●	
American White Pelican	*Pelecanus erythrorhynchos*		●	
Double-crested Cormorant	*Phalacrocorax auritus*	●	●	ex
American Bittern	*Botaurus lentiginous*	●	●	en
Least Bittern	*Ixobrychus exilis*	●	●	en
Great Blue Heron	*Ardea herodias*	●	●	
Great Egret	*Ardea albus*	●	●	
Cattle Egret	*Bubulcus ibis*		●	
Green Heron	*Butorides striatus*	●	●	
Black-crowned Night Heron	*Nycticorax nycticorax*	●	●	en
Tundra Swan	*Cygnus columbianus*	●	●	
Mute Swan	*Cygnus olor*		●	
Canada Goose	*Branta canadensis*	●	●	
Snow Goose	*Chen caerulescens*		●	
Wood Duck	*Aix sponsa*	●	●	
Green-winged Teal	*Anas crecca*	●	●	
American Black Duck	*Anas rubripes*	●	●	
Mallard	*Anas platyrhynchos*	●	●	
Northern Pintail	*Anas acuta*	●	●	
Blue-winged Teal	*Anas discors*	●	●	
Northern Shoveler	*Anas clypeata*	●	●	
Gadwall	*Anas strepera*	●	●	
American Wigeon	*Anas americana*	●	●	
Canvasback	*Aythya valisineria*	●	●	
Redhead	*Aythya americana*	●	●	
Ring-necked Duck	*Aythya collaris*	●	●	
Greater Scaup	*Aythya marila*		●	
Lesser Scaup	*Aythya affinis*	●	●	
Black Scoter	*Melanitta nigra*		●	
White-winged Scoter	*Melanitta fusca*		●	
Common Goldeneye	*Bucephala clangula*		●	
Bufflehead	*Bucephala algeola*	●	●	
Hooded Merganser	*Lophodytes cucullatus*	●	●	
Common Merganser	*Mergus merganser*	●	●	
Red-breasted Merganser	*Mergus serrator*	●	●	
Ruddy Duck	*Oxyura jamaicensis*	●	●	
Osprey	*Pandion haliaetus*	●	●	en
Northern Harrier	*Circus cyaneus*	●	●	en
Cooper's Hawk	*Accipiter cooperii*	●	●	
Red-tailed Hawk	*Buteo jamaicensis*	●	●	
American Kestrel	*Falco sparverius*	●	●	
Peregrine Falcon	*Falco peregrinus*	●	●	en
Virginia Rail	*Rallus limicola*	●	●	sc
Sora	*Porzana carolina*	●	●	
Common Moorhen	*Gallinula chloropus*	●	●	
American Coot	*Fulica americana*	●	●	
Black-bellied Plover	*Pluvialis squatarola*	●	●	
American Golden Plover	*Pluvialis dominicus*	●	●	

Table 3.—Continued.

Common name	Species name	Historical	Modern	Status
Semipalmated Plover	*Charadrius semipalmatus*	●	●	
Killdeer	*Charadrius vociferus*	●	●	
American Avocet	*Recurvirostra americana*		●	
Greater Yellowlegs	*Tringa melanoleuca*	●	●	
Lesser Yellowlegs	*Tringa flavipes*	●	●	
Solitary Sandpiper	*Tringa solitaria*	●	●	
Spotted Sandpiper	*Actitis macularia*	●	●	
Hudsonian Godwit	*Limosa haemastica*		●	
Marbled Godwit	*Limosa fedoa*		●	
Ruddy Turnstone	*Arenaria interpres*		●	
Red Knot	*Calidris canutus*		●	
Sanderling	*Calidris alba*		●	
Semipalmated Sandpiper	*Calidris pusilla*	●	●	
Western Sandpiper	*Calidris mauri*		●	
Least Sandpiper	*Calidris minutilla*	●	●	
White-rumped Sandpiper	*Calidris fuscicollis*		●	
Baird's Sandpiper	*Calidris bairdii*		●	
Pectoral Sandpiper	*Calidris melanotos*	●	●	
Dunlin	*Calidris alpina*	●	●	
Stilt Sandpiper	*Calidris himantopus*	●	●	
Buff-breasted Sandpiper	*Tryngites subruficollis*		●	
Ruff	*Philomachus pugnax*		●	
Short-billed Dowitcher	*Limnodromus griseus*	●	●	
Long-billed Dowitcher	*Limnodromus scolopaceus*	●	●	
Common Snipe	*Gallinago gallinago*	●	●	
American Woodcock	*Scolopax minor*	●	●	
Wilson's Phalarope	*Phalaropus tricolor*	●	●	ex
Red-necked Phalarope	*Phalaropus lobatus*		●	
Franklin's Gull	*Larus pipixcan*		●	
Bonaparte's Gull	*Larus philadelphia*	●	●	
Ring-billed Gull	*Larus delawarensis*		●	
Herring Gull	*Larus argentatus*		●	
Caspian Tern	*Sterna caspia*		●	
Forster's Tern	*Sterna forsteri*	●	●	ex
White-winged Tern	*Chlidonias leucopterus*		●	
Black Tern	*Chlidonias niger*	●	●	en
Mourning Dove	*Zenaida macroura*		●	
Black-billed Cuckoo	*Coccyzus erythropthalmus*		●	
Yellow-billed Cuckoo	*Coccyzus americanus*		●	
Common Nighthawk	*Chordeiles minor*		●	
Chimney Swift	*Chaetura pelagica*		●	
Belted Kingfisher	*Ceryle alcyon*	●	●	
Yellow-bellied Sapsucker	*Sphyrapicus varius*		●	
Northern Flicker	*Colaptes auratus*		●	
Olive-sided Flycatcher	*Contopus borealis*		●	
Eastern Wood-pewee	*Contopus virens*		●	
Alder Flycatcher	*Empidonax alnorum*	●	●	
Willow Flycatcher	*Empidonax trailii*	●	●	
Least Flycatcher	*Empidonax minimus*	●	●	
Eastern Phoebe	*Sayornis phoebe*	●	●	
Eastern Kingbird	*Tyrannus tyrannus*	●	●	
Purple Martin	*Progne subis*	●	●	
Tree Swallow	*Tachycineta bicolor*	●	●	
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	●	●	
Bank Swallow	*Riparia riparia*	●	●	

Table 3.—Continued.

Common name	Species name	Historical	Modern	Status
Cliff Swallow	*Hirundo pyrrhonota*	●	●	
Barn Swallow	*Hirundo rustica*	●	●	
Blue Jay	*Cyanocitta cristata*	●	●	
American Crow	*Corvus brachyrhynchos*	●	●	
Black-capped Chickadee	*Parus atricapillus*	●	●	
Brown Creeper	*Certhia americana*	●	●	
House Wren	*Troglodytes aedon*		●	
Winter Wren	*Troglodytes troglodytes*	●	●	
Marsh Wren	*Cistothorus palustris*	●	●	th
Golden-crowned Kinglet	*Regulus satrapa*	●	●	
Ruby-crowned Kinglet	*Regulus calendula*	●	●	
Gray-cheeked Thrush	*Catharus minimus*	●	●	
Swainson's Thrush	*Catharus ustulatus*	●	●	
Hermit Thrust	*Catharus guttatus*	●	●	
Wood Thrust	*Hylocichla mustelina*	●	●	
American Robin	*Turdus migratorius*	●	●	
Gray Catbird	*Dumetella carolinensis*	●	●	
Brown Thrasher	*Toxostoma rufum*	●	●	
American Pipit	*Anthus spinoletta*	●	●	
Cedar Waxwing	*Bombycilla cedrorum*	●	●	
European Starling	*Sturnus vulgaris*	●	●	
Warbling Vireo	*Vireo gilvus*		●	
Red-eyed Vireo	*Vireo olivaceus*	●	●	
Golden-winged Warbler	*Vermivora chrysoptera*	●	●	en
Tennessee Warbler	*Vermivora peregrina*	●	●	
Orange-crowned Warbler	*Vermivora celata*	●	●	
Nashville Warbler	*Vermivora ruficapilla*	●	●	
Northern Parula	*Parula americana*		●	
Yellow Warbler	*Dendroica petechia*	●	●	
Magnolia Warbler	*Dendroica magnolia*	●	●	
Cape May Warbler	*Dendroica tigrina*	●	●	
Yellow-rumped Warbler	*Dendroica coronata*	●	●	
Black-throated Green Warbler	*Dendroica virens*	●	●	
Blackburnian Warbler	*Dendroica fusca*	●	●	
Palm Warbler	*Dendroica palmarum*	●	●	
Bay-breasted Warbler	*Dendroica castanea*	●	●	
Blackpoll Warbler	*Dendroica striata*	●	●	
American Redstart	*Setophaga ruticilla*	●	●	
Ovenbird	*Seiurus aurocapillus*	●	●	
Northern Waterthrush	*Seiurus noveboracensis*	●	●	
Connecticut Warbler	*Oporornis agilis*		●	
Mourning Warbler	*Oporornis philadelphia*	●	●	
Common Yellowthroat	*Geothlypis trichas*	●	●	
Wilson's Warbler	*Wilsonia pusilla*	●	●	
Canada Warbler	*Wilsonia canadensis*	●	●	
Indigo Bunting	*Passerina cyanea*	●	●	
Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*	●	●	
Fox Sparrow	*Passerella iliaca*	●	●	
Song Sparrow	*Melospiza melodia*	●	●	
Lincoln's Sparrow	*Melospiza lincolnii*	●	●	
Swamp Sparrow	*Melospiza georgiana*	●	●	
White-throated Sparrow	*Zonotrichia albicollis*	●	●	
White-crowned Sparrow	*Zonotrichia eucophrys*	●	●	
Dark-eyed Junco	*Junco hyemalis*	●	●	

Table 3.—Continued.

Common name	Species name	Historical	Modern	Status
Red-winged Blackbird	*Agelaius phoeniceus*	●	●	
Yellow-headed Blackbird	*X. xanthocephalus*	●	●	
Eastern Meadowlark	*Sturnella magna*		●	
Rusty Blackbird	*Euphagus carolinus*	●	●	
Common Grackle	*Quiscalus quiscula*	●	●	
Brown-headed Cowbird	*Molothrus ater*	●	●	
House Finch	*Carpodacus mexicanus*		●	
Pine Siskin	*Carduelis pinus*		●	
American Goldfinch	*Carduelis tristis*	●	●	

on 12 July 1984, six on 1 June 1985, 18 on 5 June 1987, and 20 on 3 July 1987.

Blue-winged Teal (*Anas discors*).—*Anis discors* is an uncommon visitor during the summer. The peak summer count was four at Roxanna Pond on 26 July 1986, and a mean of one bird per year has been recorded at that location during the past 12 years. Though probable, breeding in the Grand Calumet River Basin has not been confirmed.

Ruddy Duck (*Oxyura jamaicensis*).—Though several nesting records are known for this species in the Calumet region, the only summer observation within the Grand Calumet River Basin was a breeding, plumed male sighted at Roxanna Pond on 24 June 1983 (seen by author). Recent nesting has occurred on the Little Calumet River floodplain (Brock 1986).

Red-tailed Hawk (*Buteo jamaicensis*).—During the summer period, this species is regularly seen flying above the floodplain. No nests have been found.

American Kestrel (*Falco sparverius*).—This diminutive falcon is seen regularly in the Calumet region during the summer. Breeding on the floodplain has not been confirmed, but a few birds might nest there.

Ring-necked Pheasant (*Phasianus colchicus*).—This introduced species has been recorded regularly throughout the summer at Roxanna Pond (seen by author) and was also noted on the DuPont property in June 1991.

Virginia Rail (*Rallus limicola*).—Though rarely seen, *R. limicola*, an Indiana "species of special concern," is a fairly common breeder in the cattail marshes on the floodplain. Summer period birds were observed at Roxanna Pond on 20 July 1982 (seen by author) and in the DuPont wetlands in 1991. Specific records at the latter site included a pair seen on 15 June, and a family group (two adults and two young) observed on 11 July 1991.

Sora (*Porzana carolina*).—The distribution of the Sora is similar to that of the Virginia Rail. June and July records include an adult with three young in the DuPont Marsh on 11 July, an adult at Ivanhoe on 11 June, and a single bird in a Clark and Pine swale on 8 June 1991. In addition, fully-feathered juveniles have been recorded at Roxanna Pond on four occasions during the fall; the largest count was five on 16 September 1995 (seen by author).

Common Moorhen (*Gallinula chloropus*).—An abundant nesting species at Roxanna Pond during the 1980's, *G. chloropus* has declined markedly in numbers during the past six years. The mean summer count between 1980 and 1989 was 17.5 per year; in contrast, the average for annual June–July counts between 1990 and 1995 was only 1.3. Peak counts of young during the halcyon 1980's included 50 on 28 June 1984 and 13 on 26 July 1986.

American Coot (*Fulica americana*).—Nesting coot populations on the floodplain, like those of Sora and Common Moorhen, have declined in recent years. During the 1980's, numerous nestings were recorded at Roxanna Pond; the peak downy young count was 15 on 16 July 1983 (seen by author). Breeding has not been confirmed at Roxanna Pond since 1990. The most recent confirmed nesting on the floodplain was in the DuPont marshes, where two young were found on 15 June 1991.

Killdeer (*Charadrius vociferus*).—This species is a common summer resident on the floodplain and breeds when appropriate nesting habitat is available. Young birds were recorded at Roxanna Pond on 5 June 1987. Peak counts during the summer period include 11 at Roxanna Pond on 25 June 1988 and four at DuPont on 15 June 1991.

Spotted Sandpiper (*Actitis macularia*).—*Actitis macularia* is fairly common along the Grand Calumet River during June and July and almost certainly breeds on the floodplain. Spotted Sandpipers have been recorded at Roxanna Pond 13 times during the summer; the peak count was three on 9 July 1988 (seen by author). In addition, two birds were observed in appropriate breeding habitat at Bongi Pond on 8 June 1991.

American Woodcock (*Scolopax minor*).—This secretive species frequents the DuPont property, where it undoubtedly breeds. Mierzwa et al. (1991) recorded woodcocks during the summer period (four on 7 June, three on 25 June, and one on 11 July 1991) at DuPont.

Ring-billed Gull (*Larus delawarensis*).—Though this species does not breed in the Grand Calumet River Basin, foraging birds are abundant throughout the summer. The peak count of 60 was observed at the Cline Avenue crossing on 24 June 1995.

Black Tern (*Chlidonias niger*).—This Indiana-endangered species, which is on the brink of extirpation as a breeding species in Indiana, formerly nested on the floodplain. Black Terns were last recorded breeding in the Grand Calumet River Basin in June 1991 when a nest containing three eggs was discovered in the DuPont marsh; the nest was abandoned by early July. Eggs were previously discovered at this site in 1986 and 1987 (Indiana Department of Natural Resources, unpubl. data). The decline of the Black Tern is graphically illustrated by the decrease that has been observed in annual summer counts. During the 1980's, a mean of seven terns per year was recorded during the summer. In contrast, only 1.2 birds per breeding season were recorded in the 1990's (based on the reports of all observers who visited the site during the nesting period). Summer period Black Terns have not been reported from the watershed since 1991, suggesting the total absence of breeding birds.

Rock Dove (*Columba livia*).—An abundant resident of nearby industrial sites, *C. livia* is frequently seen in flocks flying over the floodplain. On occasion, a few individuals can be seen feeding on the exposed mudflats at Roxanna Pond.

Mourning Dove (*Zenaida macroura*).—Small numbers of this species are seen frequently during the summer. *Zenaida macroura* probably nests, on occasion, in scrubby floodplain trees. The peak count of five individuals was taken on three different dates in 1988 (seen by author) and twice in 1991.

Black-billed Cuckoo (*Coccyzus erythropthalmus*).—Although this species may occasionally nest in floodplain shrubs or oak savanna, *C. erythropthalmus* is rare along the Grand Calumet River. The only summer record of this species was an observation at Roxanna Pond on 11 July 1981.

Yellow-billed Cuckoo (*Coccyzus americanus*).—The distribution and occurrence of *C. americanus* is similar to that of the Black-billed Cuckoo. Summer records include the observation of lone birds at Roxanna Pond on 25 July 1987 (seen by author) and at Ivanhoe on 15 June 1991.

Great Horned Owl (*Bubo virginianus*).—Active *B. virginianus* nests have been observed in the cottonwoods along the Grand Calumet River in the USX Reach.

Common Nighthawk (*Chordeiles minor*).—Although this species does not nest on the floodplain, birds forage above the river throughout the summer. Records during the summer include two birds at Roxanna Pond on 21 July 1988 (seen by author) and one on the DuPont property on 11 July 1991.

Chimney Swift (*Chaetura pelagica*).—Although the floodplain probably contains no appropriate nesting habitat for *C. pelagica*, the species is frequently seen foraging above the Grand Calumet channel and nearby ponds. A peak summer count of 20 individuals was observed over Roxanna Pond on 23 June 1990.

Belted Kingfisher (*Ceryle alcyon*).—The kingfisher is seen occasionally along the channel, and the species may nest in sandy embankments on the floodplain. Summer records include three at Bongi Pond, three at Roxanna Pond, two at the Cline Avenue bridge, and one at DuPont.

Downy Woodpecker (*Picoides pubescens*).—Although nesting has not been confirmed on the floodplain, *P. pubescens* is occasionally observed foraging in the marshes and scrubby vegetation of the floodplain during the summer. One was noted at the DuPont marsh on 25 June 1991, and two were seen at that location on 11 July 1991.

Northern Flicker (*Colaptes auratus*).—This species has been observed foraging in scrubby vegetation on the floodplain and in the oak savanna habitat on the DuPont property. The Northern Flicker was recorded at the latter site on 7 June and 11 July 1991.

Willow Flycatcher (*Empidonax traillii*).—*Empidonax traillii* is sighted regularly during the summer and very likely breeds in the floodplain marshes. Summer period records include five birds at DuPont and three at Roxanna Pond. The peak count was three at DuPont on 25 June 1991.

Eastern Kingbird (*Tyrannus tyrannus*).—The kingbird probably breeds locally on the floodplain, where it is seen regularly during the summer. Breeding period records include eight birds on the DuPont property during the summer of 1991 and singletons at Roxanna Pond in 1985, 1986, and 1991 (seen by author).

Purple Martin (*Progne subis*).—This large swallow is occasionally observed foraging over the floodplain during the summer. In addition, late July pre-migratory flocks are sometimes noted on the power lines at the Grand Calumet Lagoons (e.g., 20 birds were seen on 25 July 1995).

Tree Swallow (*Tachycineta bicolor*).—A few individuals of *T. bicolor* very likely nest locally on the floodplain wherever the requisite cavities or nest boxes are available. Many others forage over the waterways and wetlands of the Grand Calumet River. Summer period records include seven birds at DuPont, four at Roxanna, and one at the Cline Avenue bridge.

Barn Swallow (*Hirundo rustica*).—*Hirundo rustica* is an abundant summer resident of the floodplain; the species may nest beneath the bridges that span the channel. The peak summer count was 70 at Roxanna Pond on 23 June 1990.

Blue Jay (*Cyanocitta cristata*).—This widespread corvid is regularly noted on the floodplain during the summer.

American Crow (*Corvus brachyrhynchos*).—Crows occasionally forage on the floodplain during the summer. The largest count was four birds at Roxanna Pond on 23 June 1990.

House Wren (*Troglodytes aedon*).—This species breeds sparingly in oak savanna and scrubby second-growth areas on the floodplain.

Marsh Wren (*Cistothorus palustris*).—*Cistothorus palustris*, a threatened species in Indiana, is a common nesting species in the cattail stands along the channel and the adjacent marshes. Summer records include 31 birds (over 14 years) at Roxanna Pond and 35 at the DuPont marsh in 1991. Birds performing display flights were observed at the latter site on 11 July 1991.

American Robin (*Turdus migratorius*).—This widespread species is occasionally observed in the Grand Calumet River Basin during the summer. The robin may nest in oak savanna or scrubby second-growth areas on the floodplain. The peak summer period count was 30 on the DuPont property on 11 July 1991.

Gray Catbird (*Dumetella carolinensis*).—*Dumetella carolinensis* is a common summer resident on the floodplain. The species almost certainly breeds where the requisite scrubby habitat is available. The peak summer count was three on the DuPont property on 11 July 1991.

Brown Thrasher (*Toxostoma rufum*).—The thrasher is a local breeder that frequents the oak savanna habitat. Mierzwa et al. (1991) recorded this species regularly on the DuPont property.

Cedar Waxwing (*Bombycilla cedrorum*).—*Bombycilla cedrorum* is a fairly common summer resident and sporadic breeder on the floodplain. A peak summer count of four was recorded by Mierzwa et al. (1991).

European Starling (*Sturnus vulgaris*).—This invasive species, first recorded in the Chicago area in 1925 (Mlodinow 1984), is now abundant throughout the watershed. Although nesting habitat for this species is quite limited on the floodplain, flocks of brownish juveniles from nearby residential areas fly into the river corridor. By early June, these flocks are common along the river. The largest count was 25 juveniles at Roxanna Pond on 5 June 1987.

Yellow Warbler (*Dendroica petechia*).—*Dendroica petechia* is a fairly common summer resident on the floodplain, and the species probably breeds there in small numbers. Summer records include two reports from the

DuPont property—one at Roxanna Pond and another at the Cline Avenue bridge.

Common Yellowthroat (*Geothlypis trichas*).—A common species in the cattail marshes, *G. trichas* nests regularly on the floodplain. The peak summer period count was five at the DuPont marsh on 11 July 1991. One individual was performing display flights.

Northern Cardinal (*Cardinalis cardinalis*).—Small numbers of this species frequent scrubby vegetated and oak savanna habitats on the floodplain.

Indigo Bunting (*Passerina cyanea*).—This colorful species is a common summer resident in the woods of the Grand Calumet River Basin. Summer records have come from Roxanna Pond, the DuPont property, and the Cline Avenue bridge.

Eastern Towhee (*Pipilo erythrophthalmus*).—The towhee nests in oak savanna habitat on the floodplain. A young bird in fresh juvenile plumage was seen on the DuPont property on 25 June 1991.

Song Sparrow (*Melospiza melodia*).—This sparrow is a common summer resident on the floodplain, where I assume it breeds. The peak count was seven song sparrows on the DuPont property on 11 July 1991.

Swamp Sparrow (*Melospiza georgiana*).—*Melospiza georgiana* is a fairly common floodplain resident during the summer, and multiple reports have been made from both Roxanna Pond and the DuPont property. The peak count was two at the DuPont site on 25 June 1991.

Red-winged Blackbird (*Agelaius phoeniceus*).—The Red-winged Blackbird is an abundant breeding species in the floodplain marshes. The species is present at virtually any site that supports substantial cattail growth. A peak summer count of 17 was recorded on the DuPont property on 11 July 1991.

Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*).—This species, which is currently listed among Indiana's threatened birds, formerly nested on the Grand Calumet River floodplain. Yellow-headed Blackbirds are now believed to be absent as a breeding species from all of Indiana. *Xanthocephalus xanthocephalus* nested at Roxanna Pond in 1984 (at least two pair), 1985 (at least one pair), and 1986 (at least one pair). At least one pair nested in the cattails just east of the Kennedy Avenue bridge (DuPont Reach) in 1986 and 1987.

Common Grackle (*Quiscalus quiscula*).—Foraging grackles are common on the floodplain during the summer. The peak summer count was nine at the DuPont site on 7 June 1991.

Brown-headed Cowbird (*Molothrus ater*).—Small numbers of this widespread nest parasite are common along the floodplain during the summer. The peak count was two at DuPont on 11 July 1991.

Baltimore Oriole (*Icterus galbula*).—Although the Grand Calumet River Basin provides sub-optimal breeding habitat for *I. galbula*, a few individuals of this species probably nest in isolated trees along the floodplain margin. One bird was recorded at DuPont on 11 July 1991.

House Finch (*Carpodacus mexicanus*).—Beginning in the early 1980's, *C. mexicanus* invaded the Calumet region. The species is now a common resident throughout the year. Birds have been recorded at Roxanna Pond, DuPont, and the Cline Avenue bridge during the summer.

American Goldfinch (*Carduelis tristis*).—*Carduelis tristis* is a common summer resident that almost certainly breeds in the marshes along the Grand Calumet River. The peak summer count was five birds at the DuPont marsh on 11 July 1991.

House Sparrow (*Passer domesticus*).—This species nests abundantly in the suburban and industrial areas adjacent to the river. Foraging birds frequently appear along the floodplain in the summer.

Contemporary Migrants

Probably every species that regularly migrates through the Chicago area has passed over the floodplain; however, only those species actually recorded on or above the Grand Calumet River system are included in this list of migrants. All the migrants that have been recorded in the Grand Calumet River Basin are tabulated in Table 2. An annotated list of rare and uncommon migrants is provided below. The rarity of these species is listed in Brock (1986). Dominating the migrant list are 26 waterfowl species and 30 shorebird species.

Red-throated Loon (*Gavia stellata*).—One was seen on the Grand Calumet Lagoons on 1 April 1979.

Common Loon (*Gavia immer*).—A common migrant on Lake Michigan, this species occurs rarely on the Grand Calumet Lagoons.

Red-necked Grebe (*Podiceps grisegena*).—This species, rare throughout the Chicago region, has been sighted twice at the Grand Calumet Lagoons: once in November 1993 and again in November 1995.

Eared Grebe (*Podiceps nigricollis*).—A single bird was present on Roxanna Pond from 19 August 1978 until the pond froze over on 25 November 1978. Another was seen on the pond on 27 September 1980.

American White Pelican (*Pelecanus erythrorhynchos*).—One was present on the Grand Calumet Lagoons during the summer of 1967 (Brock 1986).

Cattle Egret (*Bubulcus ibis*).—A breeding-plumed bird was seen at Roxanna Pond on 26 May 1989.

Tundra Swan (*Cygnus columbianus*).—In the fall, migrants occasionally land on the Grand Calumet Lagoons. A flock of 108 birds was noted at this location on 1 December 1985.

Snow Goose (*Chen caerulescens*).—Although this species regularly migrates across the Calumet region, it rarely lands there. *Chen caerulescens* was recorded three times at Roxanna Pond (twice in the fall and once in the spring). The largest count (six) was seen on 11 April 1987.

Greater Scaup (*Aythya marila*).—Though common on Lake Michigan in the winter, *Aythya marila* is rarely seen away from the lake. The only report in the Grand Calumet watershed consists of two birds seen at Roxanna Pond on 24 April 1982.

Black Scoter (*Melanitta nigra*).—This species, which is a regular fall migrant on Lake Michigan, was seen on the Grand Calumet Lagoons on 26 October 1980.

White-winged Scoter (*Melanitta fusca*).—A single bird was seen on the Grand Calumet Lagoons on 14 March 1992 (Brock pers. obs.).

Osprey (*Pandion haliaetus*).—This Indiana-endangered species has been recorded at Roxanna Pond on four occasions during its migration period.

Peregrine Falcon (*Falco peregrinus*).—Evidence that this federally-endangered species occasionally forages on the floodplain was provided by the sighting of an adult perched on a transmission tower adjacent to Roxanna Pond on 31 October 1987 (Brock pers. obs.).

American Avocet (*Recurvirostra americana*).—A singleton was observed at Roxanna Pond on 11 May 1980.

Hudsonian Godwit (*Limosa haemastica*).—Eight birds were seen at Roxanna Pond on 11 May 1978. This record is the largest number ever recorded in Indiana (Mumford & Keller 1984).

Marbled Godwit (*Limosa fedoa*).—One bird was seen at Roxanna Pond on 10 and 11 May 1978 (Brock 1986).

Ruddy Turnstone (*Arenaria interpres*).—A flock of 15 birds was seen at Roxanna Pond on 26 May 1988.

Red Knot (*Calidris canutus*).—This species is rarely recorded away from the sandy beaches of Lake Michigan. A juvenile was seen along the muddy channel banks in the Hammond Sanitary District Reach on 17 August 1977.

Sanderling (*Calidris alba*).—A Sanderling was seen at Roxanna Pond on 28 May 1983.

Western Sandpiper (*Calidris mauri*).—This species, which is remarkably rare in the Calumet region, has been recorded four times near Roxanna Pond and the adjacent Hammond Sanitary District Reach.

White-rumped Sandpiper (*Calidris fuscicollis*).—Fall migrants have been recorded on four occasions at Roxanna Pond.

Baird's Sandpiper (*Calidris bairdii*).—Juveniles were seen at Roxanna Pond on 19 August 1988 (two) and 21 September 1989 (one).

Buff-breasted Sandpiper (*Tryngites subruficollis*).—This rare shorebird was observed on the extensive mudflats near Roxanna Pond during a period of low water on 10 September 1988.

Ruff (*Philomachus pugnax*).—A female was seen in a Gary Sanitary District settling pond on 9 and 10 August 1986 (Peterjohn 1987).

Wilson's Phalarope (*Phalaropus tricolor*).—*Phalaropus tricolor* has become quite rare in the Calumet Region during the past decade; consequently, the 28 birds recorded at Roxanna Pond on 9 May 1978 (Kleen 1979) are noteworthy.

**Red-necked Phalarope (*Phalaropus lob-*

Table 4.—The following bird species were identified within the Grand Calumet River Basin. Please note that the data are based on limited sampling; data for each reach were collected only at those sites accessible from land. For a description of the sampling areas, see Last & Whitman 2002 (this volume, pages 45–81). Abbreviations: CV = Culverts Reach, HM = Hammond Sanitary District Reach, RX = Roxanna March Reach, EC = East Chicago Sanitary District Reach, DP = DuPont Reach, GY = Gary Sanitary District Reach, and LG = Lagoons Reach.

Common name	Species	CV	RX	EC	DP	GY	LG
Red-throated Loon	*Gavia stellata*						X
Common Loon	*Gavia immer*						X
Pied-billed Grebe	*Podilymbus podiceps*	X	X		X		X
Horned Grebe	*Podiceps auritus*		X				X
Red-necked Grebe	*Podiceps grisegena*						X
Eared Grebe	*Podiceps nigricollis*		X				
American White Pelican	*Podiceps erythrorhynchos*						X
Double-crested Cormorant	*Phalacrocorax auritus*		X			X	X
American Bittern	*Botaurus lentiginosus*				X		
Least Bittern	*Ixobrychus exilis*		X		X		
Great Blue Heron	*Ardea herodias*		X	X	X	X	X
Great Egret	*Ardea albus*		X	X		X	
Cattle Egret	*Bubulcus ibis*		X	X			X
Green Heron	*Butorides striatus*		X		X		X
Black-crowned Night Heron	*Nycticorax nycticorax*	X	X		X		
Tundra Swan	*Cygnus columbianus*						X
Mute Swan	*Cygnus olor*		X				X
Canada Goose	*Branta canadensis*	X	X		X		X
Snow Goose	*Chen caerulescens*		X				
Wood Duck	*Aix sponsa*		X		X		X
Green-winged Teal	*Anas crecca*	X	X				X
American Black Duck	*Anas rubripes*	X	X				X
Mallard	*nas platyrhynchos*	X	X	X	X	X	X
Northern Pintail	*Anas acuta*		X				
Blue-winged Teal	*Anas discors*		X		X		X
Northern Shoveler	*Anas clypeata*	X	X				
Gadwall	*Anas strepera*		X				X
American Wigeon	*Anas americana*		X				
Canvasback	*Aythya valisineria*		X				X
Redhead	*Aythya americana*		X				X
Ring-necked Duck	*Aythya collaris*		X				X
Greater Scaup	*Aythya marila*		X				
Lesser Scaup	*Aythya affinis*		X			X	
Black Scoter	*Melanitta nigra*						X
White-winged Scoter	*Melanitta fusca*						X
Common Goldeneye	*Bucephala clangula*						X
Bufflehead	*Bucephala albeola*		X				X
Hooded Merganser	*Lophodytes cucullatus*		X				X
Common Merganser	*Mergus merganser*						X
Red-breasted Merganser	*Mergus serrator*		X				X
Ruddy Duck	*Oxyura jamaicensis*		X				X
Osprey	*Pandion haliaetus*		X				
Northern Harrier	*Circus cyaneus*		X				
Cooper's Hawk	*Accipiter cooperii*		X				X
Red-tailed Hawk	*Buteo jamaicensis*		X		X		X
American Kestrel	*Falco sparverius*		X		X	X	
Peregrine Falcon	*Falco peregrinus*		X				
Virginia Rail	*Rallus limicola*		X		X		
Sora	*Porzana carolina*	X	X		X		
Common Moorhen	Gallinula chloropus	X	X		X		

Table 4.—Continued.

Common name	Species	CV	RX	EC	DP	GY	LG
American Coot	*Fulica americana*	X	X		X		X
Black-bellied Plover	*Pluvialis squatarola*		X				
American Golden Plover	*Pluvialis dominicus*		X				
Semipalmated Plover	*Charadrius semipalmatus*		X			X	
Killdeer	*Charadrius vociferus*	X	X		X	X	
American Avocet	*Recurvirostra americana*		X				
Greater Yellowlegs	*Tringa melanoleuca*		X				
Lesser Yellowlegs	*Tringa flavipes*	X	X			X	
Solitary Sandpiper	*Tringa solitaria*	X	X			X	
Spotted Sandpiper	*Actitis macularia*	X	X			X	
Red Knot	*Calidris canutus*	X					
Hudsonian Godwit	*Limosa haemastica*		X				
Marbled Godwit	*Limosa fedoa*		X				
Ruddy Turnstone	*Arenaria interpres*		X				
Sanderling	*Calidris alba*	X	X				
Semipalmated Sandpiper	*Calidris pusilla*	X	X		X		
Western Sandpiper	*Calidris mauri*	X	X		X		
Least Sandpiper	*Calidris minutilla*	X	X		X		
White-rumped Sandpiper	*Calidris fuscicollis*		X				
Baird's Sandpiper	*Calidris bairdii*		X		X		
Pectoral Sandpiper	*Calidris melanotos*	X	X		X		
Dunlin	*Calidris alpina*	X	X				
Stilt Sandpiper	*Calidris himantopus*	X	X			X	
Ruff	*Philomachus pugnax*					X	
Buff-breasted Sandpiper	*Tryngites subruficollis*		X				
Short-billed Dowitcher	*Limnodromus griseus*	X	X			X	
Long-billed Dowitcher	*Limnodromus scolopaceus*		X				
Common Snipe	*Gallinago gallinago*	X	X			X	
American Woodcock	*Scolopax minor*		X		X		
Wilson's Phalarope	*Phalaropus tricolor*		X				
Red-necked Phalarope	*Phalaropus lobatus*		X				
Franklin's Gull	*Larus pipixcan*						X
Bonaparte's Gull	*Larus philadelphia*		X				
Ring-billed Gull	*Larus delawarensis*	X	X		X		X
Herring Gull	*Larus argentatus*		X		X		X
Caspian Tern	*Sterna caspia*		X				
Forster's Tern	*Sterna forsteri*		X				
White-winged Tern	*Chlidonias leucopterus*		X				
Black Tern	*Chlidonias niger*		X		X		
Mourning Dove	*Zenaida macroura*	X			X		
Common Nighthawk	*Chlordeiles minor*		X		X		
Chimney Swift	*Chaetura pelagica*		X		X	X	X
Belted Kingfisher	*Ceryle alcyon*	X	X		X		X
Yellow-bellied Sapsucker	*Sphyrapicus varius*		X				X
Downy Woodpecker	*Picoides pubescens*				X		
Northern Flicker	*Colaptes auratus*	X	X		X		X
Olive-sided Flycatcher	*Contopus borealis*				X		
Eastern Wood-peewee	*Contopus virens*				X		
Willow Flycatcher	*Empidonax trailii*		X		X		
Least Flycatcher	*Empidonax minimus*				X		
Eastern Phoebe	*Sayornis phoebe*		X		X		
Eastern Kingbird	*Tyrannus tyrannus*		X		X		
Purple Martin	*Progne subis*		X		X		X
Tree Swallow	*Tachycineta bicolor*		X		X		
N. Rough-winged Swallow	*S. serripennis*		X		X		

Table 4.—Continued.

Common name	Species	CV	RX	EC	DP	GY	LG
Bank Swallow	*Riparia riparia*		X		X		
Cliff Swallow	*Hirundo pyrrhonota*		X				
Barn Swallow	*Hirundo rustica*	X	X		X		X
Blue Jay	*Cyanocitta cristata*		X		X		X
American Crow	*Corvus brachyrhynchos*	X	X		X		X
Black-capped Chickadee	*Parus atricapillus*		X		X		
Brown Creeper	*Certhia americana*		X				
House Wren	*Troglodytes aedon*		X		X		
Winter Wren	*Troglodytes troglodytes*		X				
Marsh Wren	*Cistothorus palustris*		X		X		
Golden-crowned Kinglet	*Regulus satrapa*		X				
Ruby-crowned Kinglet	*Regulus calendula*		X				
Gray-cheeked Thrush	*Catharus minimus*		X				
Swainson's Thrush	*Catharus ustulatus*		X		X		
Hermit Thrush	*Catharus guttatus*		X		X		
American Robin	*Turdus migratorius*	X	X		X		
Gray Catbird	*Dumetella carolinensis*		X		X		
Brown Thrasher	*Toxostoma rufum*				X		
American Pipit	*Anthus spinoletta*		X				
Cedar Waxwing	*Bombycilla cedrorum*		X		X		X
European Starling	*Sturnus vulgaris*		X		X		X
Warbling Bireo	*Vireo gilvus*		X				
Red-eyed Vireo	*Vireo olivaceus*		X		X		
Golden-winged Warbler	*Vermivora chrysoptera*				X		
Tennessee Warbler	*Vermivora peregrina*		X		X		
Orange-crowned Warbler	*Vermivora celata*		X				
Nashville Warbler	*Vermivora ruficapilla*		X		X		
Northern Parula	*Parula americana*		X				
Yellow Warbler	*Dendroica petechia*		X		X		
Magnolia Warbler	*Dendroica magnolia*		X		X		
Cape May Warbler	*Dendroica tigrina*		X		X		X
Yellow-rumped Warbler	*Dendroica coronata*	X	X		X		X
Black-throated Green Warbler	*Dendroica virens*		X		X		
Blackburnian Warbler	*Dendroica fusca*				X		
Palm Warbler	*Dendroica palmarum*		X		X		
Bay-breasted warbler	*Dendroica castanea*		X		X		
Blackpoll Warbler	*Dendroica striata*	X	X		X		
American Redstart	*Setophaga ruticilla*		X		X		
Ovenbird	*Seiurus aurocapillus*				X		
Northern Waterthrush	*Seiurus noveboracensis*		X		X		
Connecticut Warbler	*Oporornis agilis*				X		
Mourning Warbler	*Oporornis philadelphia*				X		
Common Yellowthroat	*Geothlypis trichas*		X		X		
Wilson's Warbler	*Wilsonia pusilla*		X		X		
Canada Warbler	*Wilsonia canadensis*				X		
Indigo Bunting	*Passerina cyanea*		X		X		
Eastern Towhee	*Pipilo erythrophthalmus*				X		
Fox Sparrow	*Passerella iliaca*		X		X		
Song Sparrow	*Melospiza melodia*	X	X		X		
Lincoln's Sparrow	*Melospiza lincolnii*		X				
Swamp Sparrow	*Melospiza georgiana*		X		X	X	
White-throated Sparrow	*Zonotrichia albicollis*		X		X		
White-corned Sparrow	*Zonotrichia eucophrys*				X		X
Dark-eyed Junco	*Junco hyemalis*	X	X		X		X
Red-winged Blackbird	*Agelaius phoeniceus*		X				

Table 4.—Continued.

Common name	Species	CV	RX	EC	DP	GY	LG
Yellow-headed Blackbird	*X. xanthocephalus*	X	X		X		X
Rusty Blackbird	*Euphagus carolinus*		X				
Eastern Meadowlark	*Sturnella magna*				X		
Common Grackle	*Quiscalus quiscula*	X	X		X		
Brown-headed Cowbird	*Molothrus ater*	X	X		X		
House Finch	*Carpodacus mexicanus*	X	X		X		X
American Goldfinch	*Carduelis tristis*	X	X		X		X

***atus*).**—This species has been recorded only once in the Grand Calumet watershed. A single bird was seen at Roxanna Pond on 15 July 1982.

Franklin's Gull (*Larus pipixcan*).—An adult bird was observed on the Grand Calumet Lagoons on 5 November 1991.

White-winged Tern (*Chlidonias leucopterus*).—Indiana's only record of this Eurasian species is a bird seen at Roxanna Pond on 19 July 1979 (Brock 1983).

Golden-winged Warbler (*Vermivora chrysoptera*).—This Indiana endangered species was recorded at the DuPont wetlands on 23 August 1991.

Northern Parula (*Parula americana*).—This warbler, which is rare in the Calumet region, was observed in the cottonwoods along the Grand Calumet River in the Hammond Sanitary District Reach on 27 September 1980.

Connecticut Warbler (*Oporornis agilis*).—On 24 May 1991, a migrant was flushed from the oak savanna at DuPont.

Contemporary Winter Residents

Birds that winter in the Grand Calumet River corridor are primarily aquatic species that take advantage of the open water created by the effluent from local industries. All the species listed in Table 2 have been recorded on or above the floodplain during the winter (December through February). If open water were not present, far fewer species would be present during the winter. Those species marked with an asterisk (*) are rare (not present in most years).

IMPACT OF DREDGING

Considerable evidence suggests that the muddy substrate of the Grand Calumet River is contaminated (U.S. Fish and Wildlife Service 1996). The detection of mercury and PCB residues in failed eggs at the East Chicago Peregrine Falcon nest site (U.S. Fish and Wildlife Service 1996) indicates that some contaminants have entered the avian food web and poses a potential risk for birds that feed in the channel. Many birds spend extensive time foraging in this contaminated environment. For example, on 30 December 1995, 970 Mallards, plus other waterfowl species, were counted in the Roxanna Pond and Hammond Sanitary District Reaches. These birds winter on the river, apparently feeding exclusively on channel vegetation. Although the long-term effects of prolonged exposure to Grand Calumet River pollutants on birds are unknown, lengthy exposure is certainly undesirable.

Perhaps at even greater risk are the migrant shorebirds that consume members of the invertebrate infauna living within the substrate. Most migrant shorebirds depart within a few days, rendering their exposure brief, but the potential for accumulating toxins is high because they feed on organisms extracted directly from the contaminated sediment. Thus, removal of the contaminated sediment through dredging will have a positive long-term effect on the avifauna. A major concern is that the dredging operation itself might increase contamination through the resuspension of sediment during dredging. This possibility should be examined carefully within the context of the dredging methods employed.

OPPORTUNITIES

Roxanna Pond lies within a meander of the Grand Calumet River north of Roxanna Street and about 0.4 km to the west of Indianapolis Boulevard (Roxanna Reach of the Grand Calumet River). Water levels in this shallow pond fluctuate widely, and they are seemingly more dependent upon the rate of effluent discharge from local industries than on precipitation rates. Low water levels expose extensive mudflats, which provide feeding habitat for migrant shorebirds. When water levels are appropriate, the pond serves as a resting and feeding area for hundreds of spring and fall shorebird migrants. High water conditions, however, entirely eliminate the mudflats; on these occasions, shorebirds cannot land at the pond.

At least 29 different shorebird species have been recorded at Roxanna Pond. The most common species are the Lesser Yellowlegs, Least Sandpiper, and Pectoral Sandpiper. Several rare shorebirds (*sensu* Mumford & Keller 1984) have also been recorded at Roxanna Pond. Among the rarities are the American Avocet, Marbled Godwit, Hudsonian Godwit, Red Knot, Western Sandpiper, White-rumped Sandpiper, Baird's Sandpiper, Buff-breasted Sandpiper, Long-billed Dowitcher, and Red-necked Phalarope.

Shorebird numbers at Roxanna Pond vary widely from year to year depending upon the availability of mudflats during migration (April through May and July through October). In August 1988, a year when low water generated extensive mudflats, 1150 Pectoral Sandpipers were counted at the site. In contrast, during August of the following year, water levels were very high, and only 11 birds were recorded. The positive correlation between shorebird numbers and mudflat exposure holds for all other shorebird species.

As was pointed out by Helmers (1992), shorebirds need staging areas for rest before continuing their migration. For this reason, the management of water levels at Roxanna Pond would prove extremely beneficial to migrating shorebirds. The establishment of a site managed solely for migrating shorebirds would provide a sorely needed resting and feeding area for these long range migrants.

In addition to dredging, site preparation will require the restoration of a muddy substrate and the construction of a low dike and gate between the pond and the channel. The soft sediment floor will provide habitat for an invertebrate infauna, which constitutes the primary food source of migrating shorebirds. The dike will restrict flow to and from the river, allowing water levels in the pond to be adjusted through the gate. If the gate proves inadequate for regulating water levels, it may be necessary to install a pump.

Routine maintenance (e.g., Helmers 1992) will involve monitoring water levels to ensure that: 1) appropriate habitat is available during critical migration periods (April–May and July–October), that 2) pre-migration water levels are appropriate for development of an adequate invertebrate infauna on which the shorebirds can feed, and that 3) vegetation is controlled to maintain the mudflat habitat. Vegetation will be controlled by flooding during the non-migratory periods.

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ECOLOGICAL POTENTIAL OF THE GRAND CALUMET RIVER BASIN

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ABSTRACT. The Grand Calumet River and watershed have been severely degraded by industrialization and urbanization, and yet several high-quality natural areas remain intact. The degraded condition presents numerous opportunities for pollution mitigation and ecosystem restoration. In many areas of the river and watershed, biological communities are characterized by low diversity and pollution-tolerant organisms. By establishing programs of nonnative species control, prescribed burning, sediment removal, wetland establishment and extirpated species re-introduction, the Grand Calumet can be improved to reflect some of its natural history. The dredging plan for the river presents an opportunity to coordinate simultaneous improvement and restoration plans. Possibilities for each section of the river are discussed.

Keywords: Grand Calumet River, Calumet region, restoration, sediment removal

Other papers in this volume discussed the status of each major component of the flora and fauna of the Grand Calumet River study area. Here, we present an executive summary of the restoration opportunities found in the basin. These options were formulated at a meeting of all project authors and represent their collective vision for the Grand Calumet River and its associated ecosystems. This paper also includes a discussion of the impaired uses that serve as the rationale for river dredging as well as a discussion of the ways in which habitat restoration will reduce impairments.

The solutions were generated with two specific goals in mind. First, the flora, fauna and habitats need to be identified, restored, and protected. Second, pollution in the area needs to be abated. As far as possible, we hope to ensure that the watershed will possess the structural and functional attributes of a native, natural community, consistent with the Lake Michigan dune and swale ecotone.

The first step was to define the area under consideration, recognizing such an area would focus efforts to enhance the region's ecosystems but would not negate efforts to include suitable areas adjacent to the region as they become available. The second step will be to protect and enhance existing high-quality natural areas so that they can serve as biological refugia and as models to guide the restoration projects. Many other areas along the river should be enhanced and restored. These restored areas will serve as buffers for core natural areas and provide migratory pathways between natural and "least" disturbed habitats. Habitat heterogeneity and the control of exotic species are imperative for restoring and managing the watershed. To achieve our long-term goals, partnerships between the private sector and governmental agencies will be necessary to remediate degradation, to provide ongoing stewardship of lands, and to integrate ecological issues into the urban planning process.

THE STUDY AREA

The area covered in this report extends from the first dune ridge south of Lake Michigan to the ridge summit of Toleston Beach (located to the south of the Grand Calumet River) and from the Grand Calumet Lagoons in the east to the river's confluence with the Little Calumet River in Illinois at the western end (Fig. 1). The purpose of our study was to examine functional relationships among habitat areas whose hydrology is connected to and dependent on the Grand Calumet River. Historically, the borders identified for our study

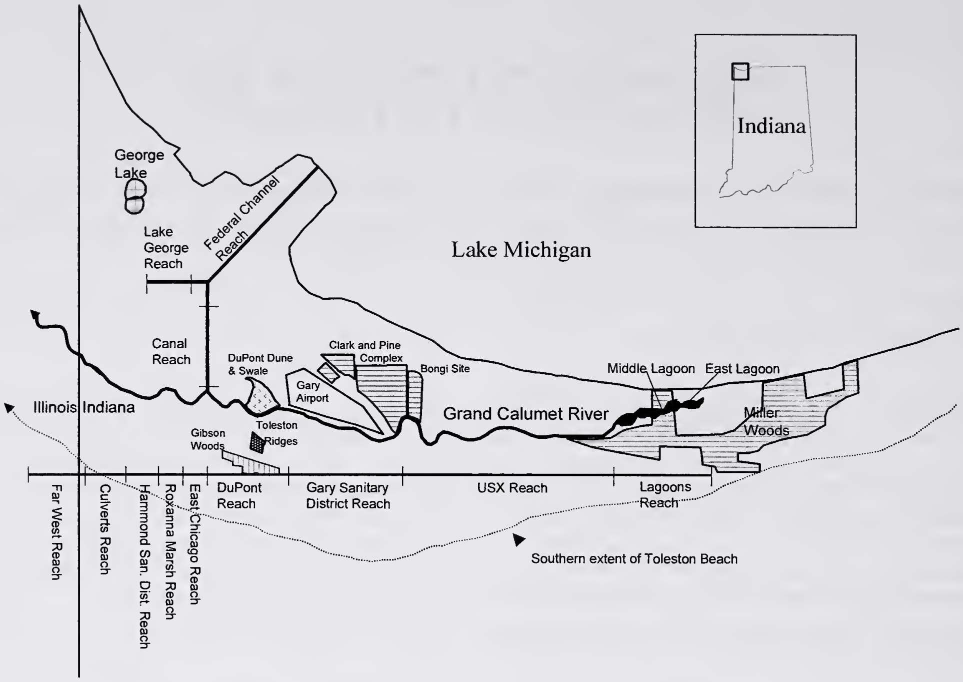

Figure 1.—Diagram of the study area. Reaches (sections) of the river referred to in the text are identified and delineated below the river diagram and along the channel leading to Lake Michigan.

marked the extent of the Grand Calumet watershed, but the hydrology of the region has been so altered by human activities that some areas have lost their connection to the river. The greatest focus has been on sites that retain some value as natural areas because these sites will benefit the most from preservation, restoration, and abatement.

The habitat quality along the shore of the Grand Calumet River is highly variable, ranging from contaminated Superfund sites to remnant natural areas that are globally significant for their rarity and diversity. The natural communities of the region were formed as the result of interaction of glacial, biotic, geologic and hydrologic factors. Industrialization has destroyed many of these sites and fragmented the rest, but those that remain retain a surprising degree of species diversity and community integrity.

The communities in the watershed formed through the mixing of species from four different biomes. The tundra species present after glacial retreat were slowly replaced by boreal forest species (Schneider 1989). Gradually, deciduous forest or woodland species replaced the boreal species in a series of changes dependent on the rates of seed dispersal and mobility. A period of warmer and/or drier climate followed, and grassland and savanna communities became established. These species invaded the region in numerous small waves as the glaciers that formed Lake Michigan receded northward (Bacone & Campbell 1983). The current communities reflect these changes. Relict species are still present in areas, but variation has occurred even within historic times. The prime communities in the current natural landscape are upland savannas, prairie remnants, and wetlands. Boreal remnants include bearberry, jack pine, white pine, and paper birch. Some woodland areas are also present. Relicts from other biomes, including tundra and deciduous forest, are located primarily to the north of the Grand Calumet River (Swink & Wilhelm 1994).

Slow landscape evolution resulted in the unique ecosystems present today. First, fluctuations in the level of Lake Michigan and currents in the lake alternately inundated and drained lake-associated habitats. These fluctuations controlled the formation and flow of the Grand Calumet River, making it a sluggish, almost swale-like watershed that drained only a small portion of the Calumet region. The wet, hilly dune and swale topography that characterizes the region is the product of slow sediment deposition on the nearshore lakebed and on the shoreline of Lake Michigan (Chrzastowski & Thompson 1992). Second, natural succession eventually changed beach formations into sand savannas and the many transitional systems in between. Migration and seed dispersal between areas was the third major process; it allowed disturbed areas to be re-colonized by native species from neighboring areas and helped to maintain genetic diversity within microhabitats. Finally, periodic fires burned across the land, clearing dead brush and preventing open areas from becoming overgrown and forested.

Industrialization and human settlement changed the ecosystems in the Grand Calumet watershed dramatically. During the past 100 years, the region's dune and swale topography has been greatly altered by sand mining, the draining and filling of wetlands, and the construction of large industrial facilities, roads, and commercial and residential areas on flattened dunes and filled swales. The Grand Calumet River has been deepened and channeled. Industries pump large quantities of effluent, greatly increasing the river's flow rate. Contamination made many areas toxic to sensitive native life forms and, in some cases, to more pollution-tolerant organisms as well.

Natural areas disturbed by industrialization and urbanization are susceptible to invasion by aggressive, exotic species. In some areas, these exotics have formed large monocultures that have choked out many other, more niche-specific species. Processes required for the creation and maintenance of local communities, such as periodic fires and migration, have been suppressed, allowing all of the communities to become overgrown. Some community types have all but disappeared from the region. Due to habitat destruction and fragmentation, the gene pools of many niche-specific native species have become dangerously small.

Despite all of the degradation that has taken place, a few high-quality natural areas remain (Swink & Wilhelm 1994). These areas are small fragments of the former landscape, which are often isolated both from each other and from the natural processes that formed them. Nevertheless, they have managed to persist relatively intact.

The Nature Conservancy, using Natural Heritage Network data, has identified the Greater Calumet Wetlands Site as an area that supports global- and state-significant biodiversity (Crispin & Rankin 1984). Eighteen natural communities exist at the site. Within these communities live more than 700 species of native plants, of which 85 are globally or state significant. More than 200 species of birds use the area, including 18 species confirmed to nest in the area that are globally or state significant. Over 20 species of reptiles and amphibians also inhabit the area, and eight of them are state significant.

Several federally-listed species are known to occur in the study area: Pitcher's thistle (*Cirsium pitcheri*), the Karner blue butterfly (*Lycaeides melissa samuelis*), and the Peregrine falcon (*Falco peregrinus*). Habitat appropriate for Indiana bat (*Myotis sodalis*) is also present, but this species has not been sighted in the area. Numerous state-listed species are found throughout the high quality habitats of the study area.

The highest quality natural areas of the study site are Miller Woods, the East and Middle Lagoons of the Grand Calumet Lagoons, Clark and Pine East, and DuPont Dune and Swale (Fig. 1). Miller Woods and Clark and Pine are the last and finest dune and swale remnants. These areas contain habitats that grade from mesic, sheltered forest into prairie and savanna. The Lagoons and adjacent ponds are some of the last local examples of potentially restorable palustrine wetlands. The Lagoons contain the most diverse macroinvertebrate fauna of any of the sites surveyed in the watershed. Clark and Pine East includes roughly 20 ha of remnant ridge and swale, which support a diverse range of habitat types, including sand savanna, sand prairie, wet prairie, sedge meadow, emergent marsh, and shrub swamp. DuPont Dune and Swale includes the largest remnant dune and swale area in the watershed (with 70 ha in the DuPont Property and additional partially degraded habitat sites in adjacent areas). Franklin's ground squirrels, declining in the state, still occur here.

The river channel itself is highly degraded and contaminated. The macroinvertebrate fauna is poor in all the reaches studied and is entirely absent from many stretches of the river. The fish are too contaminated to eat, and diving birds lose their ability to fly when the sediments coat their wings with oil. Silt deposited on the channel's banks has formed a nutrient-rich, cation-dominated sediment that favors common reed stands over native sedge flood plains. Homes, sewage disposal plants, industrial facilities and disposal sites line much of the bank; and thick growths of cattail, common reed and purple loosestrife choke out native plant and animal species in most of the marshes immediately adjacent to the channel. Dissolved oxygen concentrations in the water are often too low to support life, and nutrients released into the water support excess growth of blue-green algae.

Some improvement has occurred, and the macroinvertebrate community reflects the early stages in river recovery. A few species tolerant to some level of disturbance occur in high densities. The fish communities have also rebounded during the last decade. Abundance and diversity have improved, and these communities are primarily composed of invasive, tolerant species.

RESTORATION PHILOSOPHY AND SYSTEM-WIDE POSSIBILITIES

To evaluate the condition and restoration potential of the Grand Calumet River, we must examine every aspect of the watershed because neither organisms nor the river functions alone. Contamination of narrow river sections and/or specific organisms can have far-reaching effects on the rest of the river and its adjacent wetlands. Many changes to the watershed, such as an increase in flow rates due to industrial uses of the river, are unlikely to be reversed. For this reason, every decision about restoration must be made based on present conditions. The first goal is to restore the natural, integrated community's structure and function. When possible, certain areas may be enhanced to emulate historic conditions.

Lands adjacent to the Grand Calumet River historically consisted of a series of dunes and swales. For this reason, the species of the region are adapted to fill a wide variety of niches in both wet and dry habitats. Some species are adapted to move between different habitats in the dune/swale complex. Restoration of the area would involve recreating a complex array of contiguous habitats typical of the dune/swale system.

One method of enhancement mentioned throughout these papers is the creation of buffer zones around high quality natural areas. A buffer is a somewhat degraded, non-industrialized site adjacent to a high quality area. Although buffers are not sufficiently pristine to support diverse native communities, they can support some native species. The primary purpose of the buffers is to prevent contamination from residential and industrial sources from overflowing directly into the most sensitive natural areas. Also, they provide a surrounding habitat that is of higher quality than the polluted areas. Buffers can also be restored, when feasible, although they will usually be less diverse than high-quality natural areas.

Prescribed burning, exotic species control, and planting of selected native species are required management strategies. Burning, a natural ecosystem process, prevents succession from eliminating open, grassy habitats from the landscape (Bowles et al. 1990). Exotic species control opens areas for colonization by more diverse assemblages of species, and planting helps to ensure that disturbed areas will not simply revert to single-species stands of exotics or of invasive native species. An herbivore assemblage that is as natural as possible is also needed to maintain natural plant diversity.

Because of the presence of extensive stands of invasive and exotic species, any plans to create a continuous river corridor need careful consideration. A corridor created to facilitate migration of native, conservative plant species might easily become an invasion route for exotic monocultures. Any corridors that are created must be consistently monitored and actively maintained. Establishing diverse native species communities and avoiding exotics is an ongoing requirement for restoration efforts.

Reintroduction of extirpated species should play a role in restoration efforts. The river otter was present historically and could potentially be reintroduced to pond, lake and river habitats if these are sufficiently cleaned and protected. The American porcupine (*Erethizon dorsatum*), and perhaps the smooth green snake (*Opheodrys vernalis*), could be reintroduced into the Miller Woods area if enough good habitat is created.

Sediment clean-up would benefit the Grand Calumet watershed by clearing away large quantities of contaminants. To make moving them worthwhile, the sediments must be disposed of responsibly and have minimal impact on their disposal site's environment. After dredging (provided that all of the contaminated sediments have been removed or effectively capped) the benthic macrofauna again would have a non-toxic substrate upon which to grow. Variable banks, river depths, and bottoms should be created to provide habitat variation. Fish communities will probably return to the watershed, although it is unlikely that they will be edible.

Dredging and sediment-replacement should also be used to modify topography along the riverbanks. Banks could be dredged to recreate the shallow backwaters and marshy areas that were once present along the river. Dune replacement would help recreate the dune and swale topography. Such drastic alterations need to be carefully planned and supplemented by extensive planting and ongoing management. Further study is needed to determine the feasibility of habitat restoration in areas considered for topographic alteration.

Dredging also poses dangers to the habitats along the river and must be regulated if the benefit of dredging is to outweigh the risk. Contaminants and excess nutrients could, without proper precautions, migrate outward from the channel through aerial, side-channel, or groundwater transport of re-suspended chemicals and sediments. Some of the re-suspended chemicals may become more toxic when they are exposed to sunlight. Temporary weirs should be built as settling areas for re-suspended sediments. Dredging will create a greatly deepened, U-shaped channel, with an increased flow-rate. The increased flow will facilitate the sloughing of the river banks. Bank erosion could be minimized by adding clean sediment, planting native species, and constructing anti-erosion structures out of BioLogs™ or other materials. BioLogs™ could also serve as substrate for the growth of native plants and to create calm eddies. Micro-habitats for fish will probably be cleared away by dredging, and they should be re-created artificially. Lunker boxes, BioLogs™, half logs and other structures could be used to create artificially undercut banks and riffles for fish. Replacing dredged sediments with slag would be detrimental because contaminants can leach from the slag into the water and sediments. Instead, natural fillers such as gravel and cobble should be added. The new substrate will differ greatly from the current muck, but it would be far superior to the toxic sediments now present.

Every decision will need to balance desired benefit to the watershed with the possibility that restoration activities might actually harm the system. In many cases, these considerations may require that additional measures be taken in the course of restoration to protect against exotic species and contaminant spread, and habitat erosion.

Restoring natural systems of the Grand Calumet River can be viewed as a goal that is reached in many small many steps. Sediment restoration is one step toward cleaning up the watershed, but numerous steps must occur in this process, including wetland expansion, habitat creation, bank stabilization, and extermination of exotics. Further pollution from point and non-point sources will need to be assessed, and both average and peak pollution rates will need to be reduced. These steps could occur along with sediment clean-up, but they will be ongoing projects and cannot be performed in any meaningful and lasting way if they are considered only as an adjunct to sediment clean-up.

Continuous monitoring of all aspects of the system will be essential for charting the progress of restoration. Careful management and partnerships between involved groups will be imperative for making restoration an ongoing, rather than a sporadic and poorly planned, endeavor. Ecological considerations should be incorporated into all the steps in the planning process. Many sites, including terrestrial habitats, are indirectly affected by the river; and managing these areas is part of restoration. Furthermore, only by abating pollution and preventing re-contamination will restoration efforts be successful. Some areas may never return to historic conditions; but by decreasing pollution impacts and actively preserving and managing lands, progress can be made toward an integrated system of natural areas.

REACH-BY-REACH POSSIBILITES

The U.S. Army Corps of Engineers has divided the river into 11 reaches, or sections, corresponding to discrete dredging projects

(Fig. 1). The division between reaches is arbitrary from a habitat standpoint. The reach-by-reach possibilities for restoration will need to be incorporated into the entire study system. The possibilities for restoration at specific locations can be broken into reach-unit groupings. These, along with brief descriptions of the habitat found in each reach, are described below. These possibilities were developed in a meeting of all the authors whose papers are included in this volume. They reflect the joint effort of a group devoted to the improvement of the Grand Calumet River and the expertise of individuals in many fields of study.

Lagoons reach.—The Lagoons area contains two large tracts with high value as natural areas—the Grand Calumet Lagoons and Miller Woods, which border the Lagoons to the north and south.

Grand Calumet Lagoons: The Grand Calumet Lagoons are located at the eastern end of the Grand Calumet River where it once opened into Lake Michigan. The area immediately south of the Lagoons consists of mesic sand savanna interspersed with marsh and pond communities in swales. The area to the north borders Lake Michigan and includes unusual habitats, such as pannes. The ponds that are closely associated with the Lagoons are also valuable as rare remnants of the once-common panne-type community.

The Lagoons are divided into the West Lagoon, the Middle Lagoon, and the East Lagoon. The Middle Lagoon is considered to be the least contaminated of the three water bodies. The West Lagoon is highly contaminated and is currently under an enforcement action under the Resource Conservation and Recovery Act (RCRA). The clean-up mandated under this law will probably involve removal or capping of the contaminated sediments.

Clean-up or capping of West Lagoon sediments will probably stir up the sediment and cause contaminants to be transported into less-contaminated areas. To prevent this from occurring, before cleanup a weir could be built across the West Lagoon, near the boundary of the national park at the eastern end. After cleanup, the area should be monitored for water and sediment contamination. After contaminant levels have stabilized, the weir could be removed to allow organisms to pass between sections of the Lagoons. This process, and any other restoration activities, should be coordinated with the RCRA to assure that clean-up is efficient. If the migration of contaminants into the Indiana Dunes National Lakeshore is likely to occur, dredging and restoration efforts should be coordinated with the offices of the Indiana Dunes National Lakeshore.

Several smaller ponds associated with the Grand Calumet Lagoons also need protection. The two ponds north of the Lagoons are appropriate habitat for federally endangered plants. More research on water and sediment quality is needed to determine whether the nearby slag piles are causing contamination. Legal issues concerning the "taking" of the resident rare species need to be considered before dredging in these ponds. Contaminant concentrations should also be studied in the first row of ponds south of the Lagoons. Beyond these, the rise in elevation has probably prevented contaminants from spreading further south.

Dredging the Grand Calumet Lagoons may cause bank sloughing. This sloughing could destroy portions of the valuable Miller Woods tract. Clean sediment could be added to the dredged areas to minimize sloughing, and the banks of dredged Lagoons should then be stabilized with native vegetation in order to prevent habitat destruction.

Miller Woods: Miller Woods is one of the last and finest remnants of the dune and swale system in the watershed (Labus et al. 1999). The tract is located in a transition zone between mesic, sheltered forest areas in the east and more open prairie and savanna-dominated sites in the west. Miller Woods is the only part of the watershed containing large forest trees; and the tract is an important refuge for forest-dwelling mammals, including squirrels, voles, shrews, and bats. The area also contains high-quality amphibian habitat. Miller Woods, a large remnant area, can serve as a model for future restoration efforts. Preservation and management of this site must be a high priority.

Some of the areas surrounding Miller Woods are suitable for restoring oak savanna/hardwood habitat types, which would be valuable as buffer areas and as an addition to the isolated oak savanna habitat. Restoration efforts should include the ongoing removal of exotics, re-vegetation with native species, and the use of prescribed burning. The American porcupine (*Erethizon dorsatum*), and perhaps eventually the river otter (*Lutra canadensis*), could be reintroduced into the Miller Woods area. In the southern portion of the Miller Woods tract, the extensive illegal dumping of tires and other items is occurring. Stopping this activity would be a major step in cleaning up this valuable land. Restoration and management should be carried out based on the advice of local experts and land managers.

USX reach.—The USX (U.S. Steel Co.) reach is highly degraded along most of its length. The highest quality natural areas in the reach, both located at the far western end, are the Bongi site and a small portion of Clark and Pine. The Bongi site contains two borrow pits located north of the river. The northern pit, which is further from the river, is more contaminated than the southern pit, perhaps due to fly ash runoff from the steel mill.

Plans to restore the USX reach of the river are currently being formulated as part of a RCRA enforcement action against USX. The plans are currently on hold while the Indiana Department of Environmental Management decides whether or not to issue a water discharge permit for the river dewatering and discharge portion of the USX compliance plan. The plan for the reach's restoration, which will be paid for by USX, includes dredging within the reach to remove contaminants. Other restoration efforts may include the purchase and restoration of natural areas and the control of exotic species.

In addition to the efforts of USX, the U.S. Army Corps of Engineers plans to add deflector logs and submerged gravel weirs in this reach. Deflector logs will help to stabilize the shoreline before and after dredging. Stable shoreline and gravel weirs will provide fish habitat after dredging.

Several concerns remain. Dredging around the sensitive Bongi site at the western end of this reach may cause bank erosion, thereby destroying portions of this valuable property. Bank sloughing could also cause contamination of the Bongi ponds with sediment-laden waters from the river. The river bank should be stabilized with native vegetation to minimize this impact. The Georgia Pacific Lagoon, located south of the river, opposite the Bongi site, is also in danger of contamination due to sediment migration. One possibility is to build a levy to protect this area with tie gates to allow fish to move in and out of the Lagoon. These provisions are not included in the current restoration plans.

Restoration possibilities for the Clark and Pine property are discussed below in the section on the Gary Sanitary District reach.

Gary Sanitary District reach.—The majority of the Gary Sanitary District reach is highly degraded, but two high quality sites are located at its eastern and western ends—Clark and Pine and DuPont. An emergent marsh runs along the southern side of the Gary Airport for much of the Gary Sanitary District reach. The marsh is overgrown with cattails, which greatly limit floral and faunal diversity, and the macroinvertebrate community is highly degraded. Problems with high concentrations of PAH's (polycyclic aromatic hydrocarbons), PCB's (polycyclic biphenyls) and contaminated sediments plague the Gary Sanitary District area. The presence of a holding area for contaminated sediments probably contributes to this problem.

The Clark and Pine site has one of the highest concentrations of rare and endangered plant and animal species in the state of Indiana. The site has two main segments, separated only by Clark Street—Clark and Pine East to the southeast and Clark and Pine Nature Preserve to the northwest. The two sites are prime examples of dune and swale habitat, including extensive areas of pond, marsh, panne, sand prairie and open sand savanna. Several smaller natural areas also occur in close proximity to these sites; and they contain many of the same community types, including a jack-pine-dominated sand savanna. Within the Clark and Pine cluster, the most important restoration efforts are exotic species removal, buffer area creation and, where Clark and Pine East borders the river channel, bank stabilization.

In the rest of the reach, dredging would improve conditions by removing large amounts of contaminated sediment, thereby encouraging colonization by new species of plants and other organisms. Without ongoing habitat restoration and management, however, the shoreline is likely to refill with exotics; and no habitat diversity or connections with the broader ecosystem will be gained.

The marsh at the southern end of the airport has great restoration potential either as wet prairie or emergent marsh. Because the wetlands here are somewhat isolated from the river (and, therefore, from fish predators and the high contaminant levels present in the river water and sediments), they could serve as habitat for amphibians. To create a wetland in this area, input would be needed from the Gary Regional Airport to minimize the possibility of bird strikes by planes. Thus, the creation of open water might not be a good solution, but wet prairie or emergent marsh would attract birds that generally fly low enough to prevent problems for the airport.

The wetlands along the river might also be expanded using side channels. Dredging a channel through the abundant cattails surrounding the river and replanting with the appropriate vegetation would create a healthy wetland system, establishing an area of decreased water flow and shallow habitat ideal for turtles. The connections between the braided channels and the river would eventually close, leaving behind relatively protected wetlands. The plant species moving into the area would be influenced by water quality as well as physical topography. The ideal result would be to establish the hydrology of a sedge meadow and a conservative flora and fauna after the channel has closed. The drastic alteration of the local landscape carries with it a high risk of invasion by exotics. Careful planning, long-term continuous monitoring, and exotic species elimination would be essential to reestablish the native communities. Another alternative is to dredge the banks more shallowly than the main channel to create backwaters with the channel. These, like the dredged side channels, could potentially serve as turtle habitat; but they would also need to be actively managed to prevent exotic infestation.

In-stream restoration includes the creation of fish habitat in the river. Lunker boxes are structures built by embedding the ends of log platforms in the river banks and backfilling them with rock. These structures provide cover and shallow habitat by creating an artificial undercut bank. This approach might result in an increase in salmonids; and, because the boxes would be built in the open stream rather than in isolated backwaters and ponds, the amphibians would not be affected by the increase in salmonids. Altering river flow to establish large pool/short riffle sequences would also create new habitat in the river channel. The riffles would benefit the fish and macroinvertebrate communities by naturally aerating the water.

The top priorities for restoration in this area are 1) to abate pollution, 2) to protect and manage the Clark and Pine site, and 3) to create buffer zones and migration corridors that protect and connect the Clark and Pine and DuPont natural areas. Possible staging areas include the access road at the end of the Gary Regional airport and either side of the river at the landfill.

DuPont reach.—The largest intact dune and swale habitat in this region is in the DuPont site. Its preservation is a high priority. The DuPont site, located along the northern bank of the Grand Calumet River between Cline Avenue and Kennedy Avenue, is an example of a smooth transition between flat wetlands and the hilly dune and swale habitat. The DuPont site is one of the last places where high quality natural habitat is in direct contact with the river; therefore, the site's preservation is crucial. Wetlands, including marsh, flood plain forest, and a high quality tract of wet prairie, occur immediately adjacent to the river channel. Extensive areas of dry-mesic to wet sand prairie, dry-mesic sand savanna, and swales with sedge meadow and marsh are present slightly inland from the river's channel. A cottonwood stand grows at the bend in the river in a pond filled with dredge spoil, and this grove would be good habitat for Indiana myotis and northern myotis bats if enough trees are available. South of the river, the Toleston Ridges and Gibson Woods Nature Preserves are noteworthy; but these preserves are isolated from the Grand Calumet River by the Indiana Toll road, an effective barrier to all but the most mobile terrestrial animals. The habitat types included in this reach range from highly degraded, cattail-infested wetlands to high-quality wet prairie. Many relatively open areas remain because of accidental fires. The amphibian and semiaquatic mammal communities are quite healthy, and many birds forage here. Of all the reaches, the DuPont reach is the richest in nesting birds; and an egret rookery is found there. Creating a corridor between DuPont and Clark and Pine East would expand these high quality habitats, but functional limitations due to cultural land use would limit the corridor's success.

Contaminants are a major problem in the DuPont reach because their concentrations tend to increase as one moves further downstream. The fish are greatly affected, and oil-soaked birds are often observed in the area. Contamination affects shoreline plant habitat as well, but the depth to which the contamination penetrates the sediment and how much contamination is present in areas not immediately adjacent to the channel are unknown. The large stand of cottonwoods at the river bend probably indicates the disposal site of previous dredge spoil. Another major problem in this area is nutrient loading. Nuisance algal blooms have resulted due to deterioration in water quality. Nutrients, including nitrogen and phosphorus, probably enter from inputs upstream; but the resulting blooms first appear in the watershed in the DuPont Reach.

USS Lead currently has a cleanup proposal for this area out for public comment. One portion of the cleanup will probably focus on the channel from the river up to USS Lead. The plan for this cleanup could include stabilizing the channel's banks and preventing migration of contaminants into the adjacent, highly restorable savannas. The USS Lead property contains extensive marshy habitat that is overgrown with submergent plant species, including *Potamogeton*, *Redekia*, and *Elodea*. These submergents are useful because they extract pollutants from the water and concentrate them in their own tissues.

Because the DuPont Reach is relatively inaccessible, this area has not been studied as much as the other high quality sites in the region. More study is needed to determine the extent and impact of contamination in this reach. Difficult choices must be made between cleaning up the contaminants and/ or preserving current plant communities. The complete removal of the contaminants could mean destruction of current habitat; preventing destruction through creative engineering is a high priority in this area.

Minimal disturbance adjacent to the high quality areas (including dune/swale habitat) and the preservation of the wet prairie remnants would benefit the reach. Contamination along the remaining shoreline could be removed to the underlying sand—that is, deep enough to take out the seed bank and exotics. The banks would need to be stabilized with new vegetation and re-graded. Creating artificial wetlands by dredging side-channels (see above) would also be beneficial, provided that the natural river is not harmed.

The nutrient status of the river water must be considered when designing effective pollution abatement strategies. Excess nutrients fuel the growth of thick algal mats, which shade out other plant life. Nutrient loads in the Grand Calumet River might be reduced by bank flooding, which would allow shoreline plants to take up the nutrients. Historically, before the river was deepened and channeled, such flooding was frequent. The danger in this strategy is that contaminants can be deposited in shoreline soils. For this reason, water quality must be monitored and deemed safe before plans for riverbank flooding are made or implemented.

The removal of exotics will be important not only along the dredge channel but also within the high quality natural areas. In many locations on the DuPont property, micro-habitats exist with a limited exotic population that could be cleared manually. Ongoing plans for such removal activities would be beneficial.

A highly aggressive approach would have to be taken when dredging the channel in order to clean this particularly polluted reach. However, great care will be needed to protect sensitive habitats along the riverbank. Further study would determine the extent of contamination in areas that are associated with the river hydrologically but that are too far away from the channel to be dredged.

East Chicago Sanitary District reach.—This section of the river contains several small remnant areas of dune and swale as well as several very polluted areas. An upland meadow is present south of the river, between the Indiana Harbor Canal and the Roxanna Substation, which is located east of Indianapolis Boulevard on the north side of the river. The upland meadow at the Roxanna Substation shows great promise as a site for restoration because of its connection with the high quality DuPont Reach. Restoration could upgrade the site from a degraded remnant to a productive habitat.

Roxanna Marsh reach.—The Roxanna Marsh reach contains an open, shallow pond that was once a stopover area for shorebirds migrating between the Arctic and South America. Rising water levels over the last ten years have made the area unsuitable for these birds. The pond is now a large mudflat with very little vegetation. A number of large cottonwoods occur at several sites that had previously been filled with dredged materials. These sites are each approximately 12–15 ha in size. One is located near the Harbison-Walker property, and the other is near USS Lead. These stands might support bat populations, which are rare in the watershed. Dredging would increase the macroinvertebrate community, which would in turn provide an insect food source for bats inhabiting the area.

One option for restoring Roxanna Pond is to manage the water and vegetation levels in the spring and fall so that migrating shorebirds might use it for landing and foraging. Currently, no landing/foraging area exists in the entire Midwest, and birds that make long-range annual migrations need this habitat. This option would require that sediments in the Pond be dredged and replaced; capping the sediment is inappropriate because the added sediment could raise the bottom level to near or above the water level, making the pond unsuitable for bird landing and foraging. A dike or berm, with gates at the inlet to Roxanna Pond could be built. With the appropriate vegetation and infauna, the area would appeal to migrating birds. Some concern exists that regulating water levels in Roxanna Pond would impair salmonid migration in the river, but this concern could probably be addressed in the context of the suggested plan. A control structure around Roxanna Pond should not impede migration within the river channel; and if it did, water levels could be regulated in the spring and fall for shorebirds and left at natural levels in fall and winter to allow for unimpeded salmonid migration. Monitoring and management would be required to enhance food and shelter conditions for migrating birds. The location of a staging area should be further investigated before a final decision is made on its feasibility.

Two options are available for the cottonwood stands. They could be managed for use as bat habitat, or the trees could be cut and the areas dredged and managed as mud flats using the same proposal as for Roxanna Pond. These stands should be surveyed for bat populations and general ecosystem function before management strategies are formulated.

Hammond Sanitary District reach.—This reach is clogged with sewage refuse; and its waters are practically devoid of oxygen, making them toxic to fish. Areas adjacent to the channel are overgrown with exotic plants. Extensive dredging of both the immediate channel and the adjacent marshes will be required before any restoration can take place. Such extensive dredging will also reduce the stench that currently pervades this highly residential district. Further pollution must be prevented because currents here change directions with the seasons. Instead of flowing away from their source, the pollutants are flushed back to concentrate along the banks and in the riverbed.

One risk of dredging here is that altering the riverbed may also alter the hydrology of the area. The area is underlain by a bowl-shaped basin bordered by a brim from the expressway that causes the aforementioned reversals in current direction. If this area were leveled, the amount of water flowing to Illinois through the Grand Calumet River would probably increase. This change in flow direction might negatively impact salmonid migration. Engineers planning to dredge this reach should carefully examine the current riverbed to prevent a change in hydrology.

Culverts reach.—This area is highly degraded by an abundance of sewage. The river is practically impassable due to the depth of raw sewage. Nearby residences are subjected to unpleasant odors and an unsightly river. The water is anoxic and surrounded by cattail wetlands. Dredging most of the material from the channel will be an improvement; but contamination will persist if large portions of the riverbank, which is also highly contaminated, are not removed as well. Any removal activity will improve conditions temporarily, but recontamination will occur without a change in sewage treatment capacity.

Far West reach.—The portion of the Grand Calumet River in Illinois was not part of our study. Nevertheless, this section of the river merits discussion in any paper concerned with the river's ecology. Burnham Prairie is located approximately 2 km west of the Illinois-Indiana border. Unlike the Indiana sites that are on beach or nearshore sand deposits, Burnham Prairie is on silt-loam soils that were deposited in somewhat deeper water. Burnham Prairie is one of the last remaining black-soil prairies in the region. The site contains marsh, wet-mesic and dry-mesic prairie, and a small dry-mesic savanna grove with burr oak. Northern leopard frogs and plains garter snakes, rare throughout our study area, are common at this site.

Canal reach.—The area around the Canal reach is principally industrial with a few scattered residences. A great deal of sheet piling, cement, and slag surrounds the river. Water flow is faster here than in the other reaches, and the channel is deeper. A steel wall crosses the river to control water flow. This reach is the only connection to Lake Michigan for migrating fish; and therefore, a channel that allows fish to pass should be maintained. A wetland complex exists near the Canal, and there is a dune and swale remnant at the site where the Canal meets the Grand Calumet River. This dune/swale area would be damaged if used as a staging area for dredging.

Lake George reach.—The Lake George reach was previously dredged to Calumet Avenue. After the Federal Channel is dredged, a decision on whether the Lake George Reach should be connected to the Canal reach will be made.

IMPAIRED USES

The following list of beneficial use impairments of the Grand Calumet River was developed by the Indiana Department of Environmental Management as part of their first Remedial Action Plan (Indiana Department of Environmental Management 1991), and this list serves as justification for the planned dredging activities. Below, we will discuss how each of the impairments to river system use will be reduced by dredging and by the implementation of the restoration options presented in this document.

i) Restriction on fish and wildlife consumption.—Removing the contamination from the Grand Calumet River will improve the health of fish and wildlife communities over several generations. After dredging, the best we can hope for is to reach Lake Michigan levels of fish contamination. At that point, the same restrictions on fish consumption would apply in both water bodies. Achieving Lake Michigan levels is possible for migratory species, but catfish and carp will probably never be safe to eat. Continuous monitoring of contaminant levels will indicate when river fish are safe under Lake Michigan guidelines. No appreciable hunting occurs in the area.

ii) Tainting of fish and wildlife flavor.—Assuming that dredging removes the contaminants, tainting would presumably be reduced as well.

iii) Degradation of fish and wildlife populations.—The fish and wildlife populations will be improved only with habitat improvement following contaminant removal. Dredging removes a great deal of allochthonous material and destroys shallow water habitats. Creating artificial fish and wildlife habitat, including shallow water areas and riffles, would encourage re-colonization. Minimizing habitat fragmentation by creating corridors between natural areas would prevent rare species populations that result from a shrinking gene pool.

iv) Fish tumors and other deformities.—Fish deformities would presumably be greatly reduced, if not eliminated, with contaminant removal.

v) Bird or animal deformities or reproduction problems.—Removing contaminants from the river will improve the quality of fish (over several generations) that the birds are consuming. Therefore, long-term improvement in bird health should occur, but immediate results are not likely. The present contamination can harm migratory bird and animal populations far from the river; this long-range influence might be eliminated with contaminant removal. Pollution abatement is essential to prevent re-contamination. Another potential threat is found in the dredge spoil storage areas. Birds and other animals that land, live, or feed there risk contamination; the construction of suitable storage facilities would benefit these animals.

vi) Degradation of benthos.—Dredging would eliminate a majority of the contaminated sediment that is limiting benthic species diversity. Pollution abatement is imperative since most contamination accumulates in the sediment. Also, re-contamination from slumping banks is possible if all of the contaminants are not removed. Adding clean sediment might promote colonization by tolerant species, provided that the appropriate sediment type is used and that water quality is improved.

vii) Restrictions on dredging activities.—The contaminated sediment brought up by dredging should not pose a threat if a proper disposal plan is in place. Because of the nature of the contaminants, phototoxicity is a possibility; but if proper precautions are taken, risks can be minimized. Lining and capping the disposal areas would prevent contamination of groundwater and air.

viii) Eutrophication or undesirable algae.—Eutrophication results from poor water quality. To address this problem, nutrient inputs need to be eliminated. Dredging will not impact the persistence of undesirable algae. Diversity will probably increase when algal species re-colonize, but blue-green algae will dominate the algal flora regardless of sediment condition.

ix) Restrictions on drinking water consumption or taste and odor problems.—The long-term effects on drinking water are not at issue since public drinking water comes from Lake Michigan. However, dredging may affect the quality of the drinking water temporarily due to the movement of contaminated materials from the river into the lake. Drinking water sources must be tested during this process, and a water source further from the outlet of the Indiana Harbor Canal should be used for a short time until disturbed sediments settle.

x) Beach closings.—Dredging the Grand Calumet River will increase the rate of water flow and, as a result, will increase the number of downstream beach closings. Bacterial contamination is a real problem due to heavy sewage input. Unless sewage treatment capacity is increased in the watershed, the same amount of sewage combined with a higher rate of flow will increase the transfer of bacteria to the beaches. With restoration of some of the marsh areas along the river (e.g., Roxanna Marsh), the resulting natural filtration system should help remove some of the bacteria.

xi) Degradation of aesthetics.—Debris scattered along the shore and in the channel will be removed by dredging. However, dredging will also release a great deal of oily sediment, and the oily sheen on the river will increase, at least temporarily. Over time, a noticeable improvement in the oily appearance of the river should occur.

xii) Added cost to agriculture or industry.—Shipping capacity and cost should improve with a decrease in sediment volume after dredging.

xiii) Degradation of phytoplankton and zooplankton.—The ecosystem is currently toxic to most phyto- and zooplankton, and removing the contaminants can only improve conditions. Phytoplankton community structure is determined by the nutrients present and the flow rate. A decrease in nutrient loading is essential for improving the phytoplankton populations. Zooplankton are greatly affected by toxic sediment, so dredging would be an improvement. However, more information on resident planktonic communities is needed before a thorough estimate can be made.

xiv) Loss of fish and wildlife habitat.—Fish habitat availability will decrease because of the smooth, U-shaped channel that results from dredging. Contamination should decrease and dissolved oxygen should increase, but fish will not be attracted to the watershed unless artificial habitats are created. For this reason, habitat enhancement in the river channel is an essential part of post-dredging restoration. Other animals would also benefit from less contamination; but again, suitable habitat is needed for them to remain there. Dredging along the banks to create shallow backwaters or to eliminate exotic seedbeds could, combined with active ongoing management, create such suitable habitats.

CONCLUSIONS

The preservation and restoration in the Calumet Basin are necessary to re-create viable natural ecosystems in the wake of contamination and fragmentation caused by human settlement and industry. The historic communities in the region were diverse and formed from the flora of several biomes. Despite extensive degradation, several rare and highly valuable natural areas remain, although they represent only fragments of the native landscape. For these natural areas to persist as viable, functioning ecosystems, extensive restoration is needed. Dredging and replacement of sediments in the Grand Calumet River are first steps in the process, but preservation and management activities are required to improve the chances of success.

Dredging will remove many contaminants from the river, but it probably will not fully clean the river and may have some negative effects. To minimize the negative effects of dredging, banks could be stabilized and fish microhabitats could be artificially recreated. Pollutant concentrations in the water and sediments of the river should be monitored after dredging to insure that they stabilize at low levels. For dredging to be effective in the long term, re-contamination of the river from point and non-point sources will have to be stopped.

The habitats of the Grand Calumet River basin have been degraded not only by contamination but by fragmentation, the invasion of aggressive species, and the suppression of natural processes. These problems will also need to be addressed. Buffer areas are needed to prevent further contamination of the remaining high quality natural areas. Corridors of semi-native habitat could be created between high quality areas to allow species to migrate between them. Populations of invasive species should be eliminated to the greatest extent possible and replaced with native species. Habitats that require fire to persist should be burned periodically. Extirpated species should, when appropriate, be re-introduced to the region. The watershed should be managed to create a variety of different habitat types, and habitat for rare species might be given priority in restoration. Restoration plans need to take current conditions, such as the unprecedented rapid flow of the present-day river, into account. We may not be able to return to presettlement conditions, but efforts should be made to create a diverse set of habitats that can persist over time and that, to some extent, mimic presettlement conditions.

To accomplish the goal of an integrated, viable landscape, a new land-use ethic will have to be established. Diverse groups will need to cooperate to make restoration a consistent, long-term project. All aspects of the system will require ongoing monitoring, and plans for preservation and restoration will need to be integrated into every stage of the land-use planning process. By acknowledging that the ecologic systems of the watersheds must be understood and maintained, we can move toward the goal of an integrated, functioning landscape where human inhabitants and natural communities can successfully coexist.

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MINUTES OF THE MEETINGS OF THE INDIANA ACADEMY OF SCIENCE 1996

COUNCIL MEETING

DePauw University
7 November 1996

1. President Gammon called the meeting to order at 3:25 PM in the Olin Biology Building at DePauw University, Greencastle.

2. The minutes from the meeting of 12 April 1996 were approved.

3. The agenda was approved.

4. The President commented on his year of learning about the complexities of the organization of the Academy. He focused on the importance of communication among members of the Academy, and noted that both e-mail and the newsletter are avenues which can serve members well.

5. The Treasurer summarized the financial state of the Academy in the attached Account Summary for the Third Quarter of 1996. He noted an increase in the operating budget from the first of the year, as the balance changed from $16,984.95 to $25,825.75. He reported the Total Funds on Deposit as $42,422.73.

6. The Editor reported that the Wetlands Symposium volume is projected for publication by the end of the year. In looking at the Table of Contents for Vol. 105, he noted diversity in the disciplines represented by the articles. He also said that the cost of reprints had increased.

7. The Foundation Report was presented by Frank Guthrie. He reported the total market value of the three funds as $3,539,360, and the total income from the three as $106,656.

8. Committee Reports: Gene Kritsky reported on the activities of the National Academies of Science, of which he is President. He noted that the academies of several states have begun a self-study process. He proposes that the IAS similarly organize several focus groups for analysis and future planning.

a. Amendments Committee.—No report.

b. Library Committee.—Holly Oster provided a Library update. She noted that the Academy has a Home Page. She has also been using the Internet to locate missing IAS volumes.

c. Nominations.—Results of elections have been reported as follows: *President-Elect:* Rebecca Dolan; *Treasurer:* Edward Frazier; *Research Grants:* George Mourad; *Bonding:* Edwin Squiers.

d. Publications Committee.—Bill McKnight reported on the State Flower Selection project. The goal was to distribute posters of the state flower candidates to all of the approximately 4000 fourth-grade classes in Indiana. Approximately 26,500 votes have been registered. News releases have been sent to 102 media outlets. There is good progress on the Amphibians and Reptiles book. Work also is proceeding on the special publications about sunflowers and periodical cicadas.

e. Programs and Invitations.—The Spring meeting will be at McCormick's Creek State Park on 18–19 April 1997. There are firm invitations for the Fall 1997 meeting from St. Joseph's College for 30–31 October, and for the Fall 1998 meeting at Anderson University.

f. Research Grants.—Nelson Shaffer reported that during 1996 forty-seven senior grants were awarded which totalled $34,740. The success rate in obtaining funding was 71%. The committee was able to fund about 50% of the amount requested on each grant. He noted that the committee views these grants as seed money, and that recipients are being asked to report the results of their work to the committee, so there is an accountability system. He expressed a rationale for increasing the amount of funding which the Academy provides in grants. For Junior Grants, the committee made 21 awards for a total of $3,491.

g. Science and Society.—No report.

h. Youth Activities.—Duvall Jones reported that the Junior Academy, which meets on 8 November, and the Indiana Science Talent Search, slated for a March meeting, are running well. He noted, however, that funding for the Science Talent Search is a continuing concern. He has submitted a proposal to the AAAS for the funding of research grants written by Indiana high school students.

i. Fellows.—This year's nominees are: Kemuel Badger, Clare Chatot, Walter Hasenmueller, and Kenneth Uhlhorn. A motion was made, seconded, and passed to recommend the four nominees to the general membership at the Business Meeting.

j. Emeritus.—Dan Webster moved that Emeritus status be granted to Philip Kinsey. The motion was seconded and carried.

k. Newsletter.—Jim Berry requests that news items be sent to him at berry@butler.edu.

l. Resolutions.—Resolutions were introduced expressing appreciation to the administration and faculty at DePauw University.

m. Natural Resources.—No report.

n. Speaker of the Year.—George Bodner of Purdue University, whose expertise is Chemistry and Chemistry Education, is Speaker of the Year.

9. Local Arrangements: Announcements were made regarding parking arrangements.

10. Old Business: Special awards will be presented at the Business Meeting to Ed Frazier and Alton Lindsey. These were approved at a previous Council meeting.

11. New Business: The Academy hopes to announce the appointment of a new Executive Director at the Business Meeting. The Budget Committee will meet on 7 December, 9:30 AM, in Gallahue Hall at Butler University.

12. The meeting adjourned at 4:25 PM.

Susan M. Johnson, Secretary

EXECUTIVE COMMITTEE

Butler University
7 December 1996

1. Jim Haddock called the meeting to order at 11:20 AM in Gallahue Hall at Butler University. Academy members in attendance were: Jim Berry, Rebecca Dolan, Gary Dolph, Edward Frazier, James Gammon, Frank Guthrie, Jim Haddock, Susan Johnson, Duvall Jones, Gene Kritsky, Bill Lovell, Bill McKnight, Holly Oster, Victor Riemenschneider, and Nelson Shaffer.

2. A motion was made and seconded to approve minutes of the two meetings of the Executive Committee held on 7 November 1996. The minutes were approved as amended.

3. The agenda was approved with amendments.

4. Bill Lovell, out-going Executive Director, reported that the transfer of records to Nelson Shaffer, the in-coming Executive Director, was in progress. He thanked the Academy for the opportunity to serve. The Committee recognized Bill's contributions and expressed gratitude through a round of applause.

Nelson Shaffer thanked Bill for the orderly transfer of records. He will begin officially on 1 January 1997.

5. President's Report

A. Jim Haddock presented a Progress Report on Committee Assignments for 1997. He asked Jim Gammon and Becky Dolan to help with recruitment to fill open slots. The following committees were mentioned in particular: Research Grants will require an elected replacement for Nelson Shaffer.

After Ed Frazier agreed to serve on Amendments, one more space remained. Becky Dolan is recruiting for the Biological Survey. Gary Dolph is now looking to replace members of the Editorial Board of the *Proceedings*. Daniel Webster will chair the Emeritus Member Selection Committee. Two other members are needed. Terms of four members of the Fellows Committee expire in 1996. The High School Teacher Fellow Committee has two openings, as does the Indiana Science Talent Search. Gary Dolph added his name to the Publications Committee list, and Bill McKnight is contacting others. Jim Haddock suggested that perhaps the functions served by the Public Relations Committee, which currently has no members, should be within the responsibilities of the Executive Director. Science and Society has positions, including that of committee chair. Jim Haddock wondered if this function might be served in an *ad hoc* manner. The Science Education Advisory Committee and the Speaker of the Year Committee have openings. The *ad hoc* Corporate Relations Committee currently has no members. This may be another area of interest for the Executive Director. The committee which is listed on the books as Research Fellowship appears to be the High School Teacher Fellow Committee.

B. The President's IAS Goals for the Year include making progress on: (1) revising the Membership Directory, (2) updating and publishing a Programs and Invitations Brochure, (3) increasing the IAS financial base, (4) evaluating committee job descriptions, function, and structure, (5) improving the method for filling committees and committee oversight, (6) increasing the level of interaction, moral support, and assistance for the Junior Academy, and (7) increasing the strength of member participation in section meetings.

C. In a written statement, "It's Time for a 'Checkup'," the President underscored some of his goals further. He stated, "What I hope to accomplish as your president for 1997 is to begin (and hopefully complete) the process of thoroughly reviewing, updating and improving some of the processes that we have been doing for a number of years." To this end, he proposed establishment of an *ad hoc* committee drawing its membership from past presidents. Jim Gammon and Becky Dolan will co-chair the committee. Duvall Jones, Frank Guthrie, and Gene Kritsky also agreed to serve.

D.· Also, in keeping with the theme of self-study, "Program Requirements for Hosting IAS Meetings," a draft document prepared by Vic Riemenschneider was distributed along with a letter from him to the President. As a veteran planner of the annual meeting, he raised several issues and made a number of suggestions for consideration.

E. Jim Haddock distributed a sample "Indiana Academy Service Volunteers" sheet which could be included in the dues notice mailing to recruit membership for committees.

F. The President introduced discussion on the format of the Membership Directory which included issues of condensing, adding e-mail addresses, frequency of distribution, and recipients.

G. In discussing the Academy Homepage, Bill McKnight volunteered his students to take responsibility for the page. Nelson Shaffer will coordinate this effort with Holly Oster.

6. There was no Treasurer's Report.

7. The Secretary presented three possible formats for the Academy stationery. A motion was made, seconded, and passed to have stationery printed which will retain the features of the current model, except for the listing of officers down the left side of the page.

8. Committee Reports

A. Programs and Invitations: Upon the recommendation of Vic Riemenschneider, chair of this committee, it was moved, seconded, and passed that Anderson University be accepted as the site of the Fall 1998 and Spring 1999 meetings. The Spring sessions are to be at Mounds State Park. Interest has been expressed in hosting the Fall 1999 and 2000 meetings by other institutions. Vic brought up the issue that the Academy could facilitate the task of the Local Arrangement Chairs, and the Program and Invitations Committees. He suggested, for example, that the committee appointments be made a minimum of two years, that the Executive Director be on the Local Arrangements Committee, and that the Program Committee prepare the meeting budget. The President suggested that Vic present a specific proposal to the *ad hoc* committee.

The Spring meeting will be April 18–19. The Canyon Inn, in Spencer, Indiana, is holding rooms only until January 18. It is anticipated that field trips will be held on Saturday morning. The evening program could include self-study discussion groups.

B. Local Arrangements: Duvall Jones reported that plans are progressing for the Fall 1997 meeting at St. Joseph's College. Bill McKnight raised the question of whether there should be an Academy brochure. The issue of a membership brochure was also discussed. Bill volunteered to look into this further.

C. Newsletter: Jim Berry requested that members send him information about events and contacts. The idea of featuring distinguished members in the Newsletter was raised.

9. As Unfinished Business, Jim Gammon asked that the issue of criteria for Fellows selection be placed on the agenda for the next meeting.

10. As New Business, Ed Frazier presented three letters of agreement for Committee approval.

A motion was made, seconded, and passed to appoint Bill McKnight as Managing Editor of Publications and Chair of the Publications Committee for the third year of a three-year term.

A motion was made, seconded, and passed to appoint Gary Dolph as Editor of the *Proceedings* for the 1997 calendar year.

A motion was made, seconded, and passed to appoint Nelson Shaffer as Executive Director for the 1997 calendar year.

11. The next meeting was scheduled for Saturday, 22 February 1997 at 9:30 AM, in Gallahue Hall, on the Butler University campus.

12. The meeting was adjourned at 1:20 PM.

Susan M. Johnson, Secretary

MINUTES OF THE MEETINGS OF THE INDIANA ACADEMY OF SCIENCE

1997

EXECUTIVE COMMITTEE

Butler University
22 February 1997

1. President Haddock called the meeting to order at 9:40 AM in the Garden House in Holcomb Gardens at Butler University. Academy members in attendance were: Gary Dolph, Edward Frazier, James Gammon, Jim Haddock, Susan Johnson, Bill McKnight, Holly Oster, Victor Riemenschneider, and Nelson Shaffer.

2. The agenda was approved.

3. A motion was made, seconded, and passed to approve the minutes of the meeting of 7 December 1996.

4. The Treasurer, Ed Frazier, summarized his report in the attached Account Summary for the Fourth Quarter of 1996. He noted that the balance on hand of $11,949.97 in the Operating Fund, as of 31 December 1996, represented a deficit of about $5,000 in relation to the balance on 1 January 1996. The Total Restricted Funds balance was $61,548.56. The sum of the Funds on Deposit was $73,498.56. The Treasurer viewed the financial condition of the Academy to be healthy. The report was accepted.

5. The Executive Director, Nelson Shaffer, introduced a number of topics and action items. He reported that as of 21 February 1997, dues had been received from 441 members, including one Life Membership at $500, two Corporate members at $250 each, and three Institutional members at $50 each. This number is not quite half of the total expected membership. He reported receipt of $12,964.

There have been three deaths since the last directory was published.

The Executive Director would like to prepare three separate brochures to advertise the Academy to industry, institutions, and the public.

Nelson Shaffer and Bill McKnight described the work they have done in preparing the 1997 Academy *Yearbook*. Nelson distributed a sample of pages from the proposed reformatting of the membership roster. Bill distributed a draft of the other sections of the *Yearbook*. The two are striving for a presentation which will be cost-efficient, as up-to-date as possible, and aesthetically pleasing. Following discussion of a target date for publication of the *Yearbook*, a motion was made, seconded, and carried that 1 March 1997, would be the cut-off date for inclusion of new dues-paying members in the membership directory.

On the issue of including advertising in the *Yearbook*, a motion was made, seconded, and carried to accept advertisements tastefully presented.

It was decided that the cover of the *Yearbook* would be blue this year. The decision was also made to remove the section affiliation, while including an e-mail address, for each person listed. The President thanked Nelson and Bill for their extensive work on this project.

6. In the absence of the President-Elect, the President reported that Becky Dolan is directing attention to a membership brochure and is co-chairing the *ad hoc* Committee on Committees with Jim Gammon. This committee plans to bring suggestions to the Spring meeting.

7. The Secretary distributed stationery to those present.

8. Gary Dolph, Editor of the *Proceedings*, reported that both issues of Vol. 103 are in blue line. He projected the end of March for their arrival date at the State Library, from which they will be shipped to the membership. He also reported that Vol. 105, 1–2, was on disk, and would be produced in Bloomington.

The Editor presented the draft of a document which requests an increase in state funding for the publication of the *Proceedings* from $8,811 to $20,000. This would require an amendment to the budget of the Indiana State Library. A motion was made, seconded, and passed that the *ad hoc* Committee on Appropriations move forward with this proposal. The committee consists of Co-chairs Dolph and Shaffer, as well as Becky Dolan, Ed Frazier, and Bill McKnight.

9. In the absence of the Newsletter Editor, the President reported that March 1 was the deadline for receipt of items.

10. President Haddock reported that he was researching the criteria for selection of Academy Fellows.

He recognized the work of Duvall Jones, Chair of the Youth Activities Committee, who obtained $1500 from AAAS for 1997 for support of high school science research.

He noted that Wayne Mueller, who was appointed to work on public relations for the Academy, has been quite ill and unable to work in this area.

a. Programs and Invitations (Vic Riemenschneider) reported on the Spring Meeting at McCormick's Creek State Park. Registration information will be in the Newsletter and will be sent to Ed Frazier. The program schedule includes on Friday, 18 April: Executive Committee, Council Meeting, Discussion: Preparing the Academy for the New Millenium, followed by dinner and Leslie Real speaking on "Ecology of Infectious Disease". On Saturday, there are two field trips: Geology of the park, and Natural history.

1998 Meeting.—Anderson University will not be able to host the 1998 Fall Meeting due to scheduling difficulties. Other options are being explored for a host institution.

Composition of the Committee.—Vic proposed a change in the By-laws which would streamline the committee and ensure continuity from year to year. A motion was made, seconded, and passed that this proposal be forwarded to the Amendments Committee for further study.

Summary of Hosting Requirements.—Vic presented a document which details program requirements for hosting academy meetings. The President suggested that Vic make specific recommendations to the Executive Committee and work with the Executive Director so that information can be included in the Operating Manual.

b. Amendments (Ed Frazier)

A document which proposes Constitution and By-law changes in the following areas was presented: Make the Constitution and By-laws conform to current practices; Modify the position of Director of Public Relations; Create the position of Editor of the Newsletter; Make the quorum of the Council more in line with Robert's Rules of Order and clearly define the role of the Council; Redefine the make up and role of the Executive Committee; Give the Youth Activities Committee the responsibility for awarding student research grants; Clearly define which type of membership receives the *Proceedings* and what is being received; Create the position of Historian and eliminate the position of Necrologist; Remove superfluous portions of the Constitution. It is anticipated that the Committee on Committees will suggest additional changes later in the year.

c. Publications (Bill McKnight)

The Executive Committee suggested that 1200 copies of the *Yearbook* be produced. Bill has engaged in discussions with the Chicago Botanical Gardens about the Sunflowers volume. A motion was made, seconded, and passed to authorize the Treasurer to sign a memorandum of agreement on publication of *The Sunflower Family in the Upper Midwest* by Thomas Antonio and Suzanne Mass.

A motion was made, seconded, and passed which authorizes the Treasurer to sign a letter of agreement between Wadsworth Publishing Co. and the Academy on the publication of *Indiana Amphibians and Reptiles*.

12. Old Business.

The issue of standardizing the name of the *Handbook of Operations* was discussed.

It was noted, in relation to the Index of Vol. 103, that the Academy has taken stands on political issues in the past.

13. New Business.

Holly Oster distributed hard copies of extensive work which she has accomplished on the IAS Home Page. In discussion of the amount of information which should be available on line about individual members, the consensus was that the Academy should be conservative. A suggestion was made that only the names and addresses of key officers be included.

Jim Haddock thanked Holly for the fine job she has done on the Home Page.

Bill McKnight reported on the State Flower Project. More than 27,000 fourth-grade students throughout Indiana have voted for their choice of a new state flower. The winner is the Fire Pink. Bill mailed a news release to 120 newspapers, TV and radio stations.

The need was expressed for public relations that represents the best science and is well-coordinated.

15. The next meeting will be on 18 April 1997 at McCormick's Creek State Park.

16. The meeting was adjourned at 1:12 PM.

Susan M. Johnson, Secretary

EXECUTIVE COMMITTEE AND COUNCIL

McCormick's Creek State Park

18 April 1997

The meeting of the Executive Committee was called to order by President Jim Haddock at 1:10 PM in the Canyon Inn, McCormick's Creek State Park. Academy members in attendance were: James Berry, Rebecca Dolan, Gary Dolph, Edward Frazier, James Gammon, Jim Haddock, Walter Hasenmueller, Susan Johnson, Duvall Jones, Bill Lovell, Bill McKnight, Holly Oster, Victor Riemenschneider, Nelson Shaffer, Edwin Squiers, and Terry West. The Executive Committee meeting concluded at 3:10 PM, and the President called the Council meeting to order at 3:30 PM. The Council adjourned at 4:45 PM. Information disseminated and business transacted by the two bodies is summarized below. The majority of topics were addressed in both meetings. Topics which were considered in only one meeting are so designated.

1. The Executive Committee approved the minutes of its meeting of 22 February 1997, and the

Council approved the minutes of its meeting of 7 November 1996.

2. Treasurer Ed Frazier summarized his report in the attached Account Summary for the First Quarter of 1997. He noted that the Operating Fund balance of $24,278.47 reflected receipt of dues. The Total Restricted Funds balance was $58,566.98. The total Funds on Deposit was $82,845.45. The Treasurer indicated that the finances are in order. His report was accepted.

3. Executive Director Nelson Shaffer reported that he had completed the required paperwork for the IAS to be an affiliate of the AAAS. At this time, about half of the IAS membership has paid dues for the 1997 calendar year. A second notice will be sent to those who have not paid.

4. Editor Gary Dolph reported that Volume 103 (1–2) of the *Proceedings* would be delivered to the State Library during the week of 21 April, and would be sent to members shortly thereafter. Volume 105 (1–2) has gone to the publisher, and Volume 105 (3–4) is in progress.

A motion was made, seconded, and carried that the minutes of the Executive Committee and Council meetings from April 18 be merged as an experiment for the purpose of saving space in the *Proceedings.*

5. Jim Berry, Newsletter Editor, announced that the abstract form for papers for the Fall meeting would be included in the June edition. He requested that members send him information on scheduled events of general interest. Submissions may be sent in the form of an e-mail message to Berry@butler.edu.

6. President Haddock reported that he had been working with a variety of IAS representatives on items such as the Spring Meeting, *Yearbook*, and the site of the 1998 Fall Meeting.

7. Committee Reports:

a. *Ad hoc* Committee on Committees. (Dolan/Gammon)—The co-chairs of this committee led a discussion following the Executive and Council meetings on the organizational structure of the IAS.

b. Academy Foundation.—The President reported that there had been activity with regard to the holdings.

c. Programs and Invitations.—(Riemenschneider) The committee chair moved acceptance of the 1999 invitation of the University of Southern Indiana to hold the Fall meeting on campus early in November and to hold the Spring meeting at New Harmony. Motion carried.

The motion was made, seconded, and carried to accept the invitation of Park Tudor School to hold the Fall 1998 meeting on 30 October at the Indianapolis facility. During discussion interest was expressed in designing the meeting around issues in science education.

At the Executive Committee meeting, the committee chair reported that he continues to develop the document *Program Requirements for Hosting Indiana Academy of Science Meetings.* The President asked that the Programs and Invitations committee make recommendations with regard to questions raised, such as: Should the Fall and Spring meetings be organized by one institution, or should each meeting be viewed as totally independent? What should the scope of the program for the Spring meeting be? Should host institutions be allowed to obtain sponsorship from industry? Would such industrial sponsors be required to be members of IAS? The motion was made, seconded, and carried authorizing the Treasurer to sign a contract for a meeting at Turkey Run State Park on 17–18 April 1998, and to include a deposit of $300.

d. Local Arrangements.—(Jones) Progress in planning for the Fall Meeting on Friday, 31 October 1997, at St. Joseph's College was reported. Members should note that the meeting will be held on Central Standard (i.e., Chicago) time. A number of amendments are anticipated.

f. Publications.—(McKnight) The chair projected possible publication dates for several books: *Natural Heritage of Indiana*, 1997; *Amphibians and Reptiles*, 1997; *Sunflowers*, 1998 or 1999.

The chair described work on the 1997 *Yearbook.* A motion was made, seconded, and carried by Executive Committee members to approve the cost of producing the *Yearbook*. The actual cost will reflect the amount of advertising which can be sold to appear on the booklet covers.

g. Auditing.—(Waltz) A motion was made, seconded, and carried to accept the Auditor's Report.

h. Fellows.—(Schmelz) In response to a request from the Fellows Committee for help in clarifying the criteria for selection of Fellows, Council members discussed the question of what it means to be a Fellow of the IAS. The consensus was that the IAS honors a person by awarding the fellow designation, and that the person needs to have achieved recognition in science, as a teacher or researcher, and to have contributed to the operation of the IAS. The criteria for Fellow should include both science and service aspects.

i. IAS Representative to the Indiana Natural Resources Commission.—(Schmelz) The Commission sets general policy. This spring it is considering issues related to sports fisheries.

j. IAS Representative to the NAAS.—(Kritsky) The NAAS has a website which is designed to facilitate communication between state academies. The National Center for Science Education has suggested that each state academy have a local liaison who could be contacted on issues related to "Scientific Creationism." In announcing that he had received a National Service Award from NAAS, Kritsky thanked the IAS for the opportunity to serve.

k. Research Grants.—(Chatot) Twenty-three proposals, requesting a total of $23,356, were received in the Spring Senior Academy competition. The committee recommended funding for 18 proposals, totaling $13,720. This represents a 78% success rate and funding of 54% of the monetary request.

l. Nominations and Elections.—(Conklin) Nominations are sought for the following positions: President-Elect, Secretary, Foundation Committee, Research Grants Committee.

m. Emeritus.—(Webster) A motion was made, seconded, and passed that Ernest M. Shull, a 26-year member and author of *Butterflies of Indiana*, be granted emeritus status.

8. Unfinished business

a. Holly Oster continues to update the IAS home page.

b. The question was raised as to whether there would be necrology reports at the Fall business meeting. Bill McKnight will write a note for the newsletter asking friends and colleagues to inform the Academy of the death of members.

9. New business

Bill McKnight suggested that Special Awards be approved at the Spring meeting and awarded at the Fall meeting. The President will consider appointing a Special Awards committee which would develop criteria.

10. The next meeting of the Executive Committee will be on 19 July from 9:30–12:00 at Park Tudor School. The next meeting of the Council will be on Thursday, 30 October at St. Joseph's College.

EXECUTIVE COMMITTEE

Park Tudor School

19 July 1997

1. The meeting was called to order by President Jim Haddock at 9:35 AM in Foster Hall at Park Tudor School. Academy members present included Rebecca Dolan, Gary Dolph, Edward Frazier, Jim Gammon, Jim Haddock, Susan Johnson, Duvall Jones, Bill McKnight, Vic Riemenschneider, and Nelson Shaffer. The Head Master of Park Tudor welcomed the group to campus.

2. The minutes, which recorded events of the Executive Committee Meeting and the Council Meeting of 18 April 1997, in a single document, were approved.

3. The agenda was approved.

4. Treasurer Ed Frazier presented details of revenue and expenditures and then summarized his report in the attached Account Summary for the Second Quarter of 1997. He reported an operating fund balance of $20,054.32. The Total Restricted Funds balance was $22,841.20. The Total Funds on Deposit was $42,895.52. The Treasurer indicated that the Academy appeared to be in good financial condition. The report was accepted.

5. Executive Director Nelson Shaffer reported that a second dues notice had been sent out and that 413 regular members had paid to date. He forwarded the bill for membership of IAS in NAAS to the Treasurer to be paid. He received a request from the Physics Department at North Carolina State University for permission to include three papers from the *Proceedings* of 1939, 1940, and 1941, in a volume: *The Cornelius Lanczos Published Collected Papers with Commentaries.* The occasion is the Centenary Celebration of the contributions of this scientist. The Committee supported the idea that permission be granted along with the request that appropriate citations be made. Shaffer has made arrangements to use campus mail at Indiana University for members of IAS who are on the IU campus. This will result in savings for the Academy. He was in the process of sending mailing labels to section chairs. He noted that AAAS has requested a letter of support for the 150th anniversary. He announced that the *Yearbook* had been distributed.

6. Gary Dolph, Editor of the *Proceedings*, reported that Volume 105 (1–2) was anticipated to be distributed in August or September. He presented an overview of the status of manuscripts awaiting publication. Volume 105 (3–4) was to go to the printer on September 1. For Volume 106 (1–2), ten manuscripts were ready and two or three more would be accepted. He listed five manuscripts which were in revision and three in review. Official notification of page charges will appear in Volume 105 (1–2) After that time members will be charged $10 per page and nonmembers, $70 per page. *The Bedford Handbook for Writers* is the reference for punctuation and grammar.

7. With regard to the Newsletter, Bill McKnight reported that the next issue would be mailed early in August and would contain information about the Fall meeting. There was discussion about the timetable for selection of the Speaker of the Year and publicizing of the speech.

8. President Haddock reported the death of Wayne Mueller. There was discussion of possible ways to use the $960 in memorials donated to the Academy. Suggestions included an honorarium for the Speaker of the Year, scholarship for a Junior Academy member, addition to the Past Presidents' Fund. The Treasurer feels the money could be used for a single project.

9. Committee Reports:

a. Ad hoc Committee on Committees.—(Dolan/Gammon) Recommendations were sent to the Amendments Committee.

b. Amendments.—(Hansen/Frazier) Discussion of proposed Constitution and By-law changes occurred. The changes were described under the following categories: (1) Make the Constitution and By-laws conform to current practices. (2) Removing the position and committee of Director of Public Relations and Academy Relations to the State Committee and place the Director of the Junior Academy of Science on the Executive Committee. (3) Create the position of Editor of the Newsletter. (4) Make the quorum of the Council more in line with Robert's Rules of Order. (5) Clearly define which type of membership receives the *Proceedings* and what is being received. (6) Create the position of Historian and eliminate the position of Necrologist. (7) Remove superfluous portions of the Constitution. (8) Revise Committees and Committee Functions.

The title of the Biological Survey Committee was revised to "Biodiversity and Natural Areas Committee." There was discussion of the elimination of the Science and Society Committee and the Science Education Advisory Committee. The President stated that the work of those groups needed to be carried on, but under a different format.

A motion was made, seconded, and carried that the President would write a letter nominating Duvall Jones to the Advisory Board for the development of a Statewide Assessment Model for K-12 Science Education.

The Constitutional and By-law proposals were to be distributed as appropriate to permit voting by the Council.

c. Programs and Invitations.—(Riemenschneider) Copies were distributed of the document "Program Requirements for Hosting Indiana Academy of Science Meetings." The President thanked the Chair for work on the document.

Turkey Run Inn has been reserved for the Spring meeting, 17 April 1998. Space will be rented for meetings, but rather than providing for a banquet, dinner will be done individually in the dining room. The Fall meeting of 1998 will be at Park Tudor School. The Spring and Fall Meetings for 1999 will be hosted by the University of Southern Indiana.

d. Local Arrangements.—(Jones) Progress was reported. There was discussion of a possible workshop on use of technology for teaching.

Duvall Jones then reported on the arrangement with Cinergy for support of the Indiana Science Talent Search. The one-time grant of $2500 will include: $1000 to the winning student; $1000 to the Academy for operations; $500 to the winning student's teacher for equipment. The award will apply to research in the areas of environment, energy generation, and pollution prevention. The arrangement may be continued if both parties are satisfied with the outcomes.

Dr. Jones introduced a resolution regarding the inclusion of science in the ISTEP testing program. The item will be discussed at the next Executive Committee meeting.

e. Publications.—(McKnight) The Chair reported on the status of various projects. The Committee is not moving ahead with the *Breeding Bird Atlas* project at this time. The *Natural Heritage* book is expected to be ready this fall. There has been a reduction in the State Library holdings of overprinted volumes of the *Proceedings*.

10. Unfinished Business

The President circulated a report on the status of the Academy Foundation. Recent transactions reflect changes in the John S. Wright Fund holdings with a view toward diversification.

11. New Business

a. Recognition will be made of Bill Lovell's gift to the Past Presidents' Fund.

Discussion was held about producing a very attractive certificate of recognition for Special Awards.

b. The issue of having an annual yearbook or a biannual publication with an abbreviated version in the off-year was discussed. Bill McKnight presented an estimate of $3590 to produce 1000 copies of a 1998 yearbook.

c. Rebecca Dolan expressed interest in reworking the membership brochures.

12. The meeting was adjourned at 11:50 AM. Members toured the Park Tudor Campus with an eye toward use of the facilities for the 1998 Fall meeting. The Committee discussed the role of mass media in science as a possible featured theme for the meeting, and was favorably impressed by the facilities.

Susan M. Johnson, Secretary

EXECUTIVE COMMITTEE

St. Joseph's College
30 October 1997

Note: No official copy of the minutes from this meeting is available. Following is a brief list of some matters discussed at the meeting, taken from a member's personal notes.

1. It was announced that page charges for the *Proceedings* would be assessed for papers submitted after 21 October 1997.

2. A draft of the new membership brochure was passed out.

3. Volume 103, 1–2 of the *Proceedings* has been printed but had to be trashed because of a poor printing job.

4. There was a discussion about reallocation of stock in the endowment to provide for more income to the Academy.

5. A paid Fall meeting registration form must accompany the submitted abstract before it will be accepted and published in the meeting program booklet.

6. The awards to be given by the Academy are: President's award to Bill Lovell; Special Service award to Bill and Faye Daily. These must be approved by the Council.

7. The Academy will have a room at the new State Museum.

8. The next meeting of the Executive Committee will be at Butler University on 13 December.

COUNCIL MEETING

St. Joseph's College

30 October 1997

Note: No official copy of the minutes from this meeting is available. Following is a brief list of some matters discussed at the meeting, taken from a member's personal notes.

1. There is a cost overrun on the printing of the Academy directory.

2. The Executive committee will vote on the membership brochure at the Spring meeting.

3. Cinergy, Inc. is supporting high school research through the IAS Youth Activities Committee.

4. The Council directed the Trustees to look at a better balance between income and growth of the investments in the endowment.

4. Charles E. Wier was approved as an Emeritus member.

5. Abstracts for the Fall meeting must be accompanied by a paid registration for the meeting.

6. Election results are: Marion Jackson, President-Elect; Robert Dale, Secretary; Wendell McBurney, Foundation, and Anne Spacie, Grants committee.

7. There is a new booklet listing the requirements for hosting a meeting. The Spring meeting for 1998 will be at Turkey Run State Park, and the Fall meeting will be at Park-Tudor School.

8. Tom Simon (Indiana Biological Survey) said that they wanted to have a location in northwest Indiana, and needed someone (paid) to run the center until revenue started coming in. He recommended purchasing a building for the center. No action was taken.

9. Academy awards were approved for: Scholar—Charles Heiser; Special Service—Bill and Faye Dailey; Outstanding Contributions—Bill Lovell.

10. Addresses in the Academy Yearbook are for IAS business only. Labels for non-profit organizations may be made available at the discretion of the Executive committee.

EXECUTIVE COMMITTEE

Butler University

13 December 1997

Note: Secretary Susan Johnson was ill. Notes taken by Nelson Shaffer.

Treasurer Ed Frazier reported income of $24,640, which is about the expected amount. A handout stated current budget. The operating budget started at $11,950 and is now $9,607 with a few bills still anticipated, mainly from Gene Kritsky's trip to the AAAS meetings. Costs for *Proceedings* have gone down but there is a deficit in Publications because that fund paid $19,000 for support of the *Natural Features of Indiana* book. Research Funds has paid student grants and will be replenished from the Foundation Funds. Other funds are status quo.

Checking account is about $1000, and we have $28,000 in a money market fund. The operation budget will show a deficit. Attendance at the St. Joseph's Fall meeting was 292 Senior academy and 128 for Junior academy. The meeting brought in $7151 and expenses were greater by $1266. Overall operating budget was about $2000 over anticipated costs due to special mailing of by-laws and yearbook expenses.

Executive Director Nelson Shaffer noted that membership for 1997 was 1001. Dues statements for 1998 were sent in December and about 25% of members have responded to date. Becky Dolan will develop a membership brochure and attempts will be made to attract corporate and institutional members. There was discussion of methods to increase membership and funding for *Proceedings*.

The Foundation Committee report from Frank Guthrie was read by Shaffer. Frank had transferred about $67,000 from the invested income account. He anticipates that about $90,000 from that account will be available for current obligations.

Gary Dolph reported that IU will print Volumes 105 and 106 of the *Proceedings*. He expects Volume 106 will be done by mid-January. Any new papers will be assessed page charges.

Becky Dolan is completing committee assignments but still needs a few volunteers. She is trying to increase Junior Academy involvement.

Details of the Spring Meeting were discussed. Concern was expressed about notifying honorees. The Awards Committee will be responsible for this duty. Bill McKnight is having award scrolls made. Executive Director Shaffer will be responsible for resolutions.

Jim Haddock presented a list of contact information for officers and committee chairs and a summary of concerns. He stressed the need for communication with the Junior Academy. A workshop on the role of mass media on high tech communication was discussed. The Fall meeting will be held 29–30 October at Park Tudor School in Indianapolis. Holy Oster reported on the IAS web site. The secondary school science program was awarded $1700 by AAAS through the efforts of Duvall Jones.

The meeting adjourned at 10:45 AM.

MINUTES OF THE MEETINGS OF THE INDIANA ACADEMY OF SCIENCE 1998

COUNCIL MEETING

Turkey Run State Park
17 April 1998

President Dolan called the meeting to order at 1:05 PM. Members present: Rebecca Dolan, Robert Dale, Edward Frazier, Gary Dolph, James Haddock, Nelson Shaffer. Other Council members and guests present: Frank Guthrie, Bill McKnight, Jim Berry, Holly Oster, and Marion Jackson.

Minutes of the IAS Executive Committee meeting of 13 December 1997 (prepared by Nelson Shaffer in Secretary Susan Johnson's absence) were distributed and discussed. Gary Dolph asked that the fifth paragraph be changed to read, "Gary Dolph reported that IU will print Volumes 105 and 106 of the *Proceedings*. Any new papers will be assessed page charges." Minutes of the IAS Budget Committee meeting of December 1997 (also by Nelson Shaffer) were also distributed and discussed. Gary Dolph moved that we accept both executive and budget meeting minutes subject to further checking. Accepted.

Ed Frazier distributed and summarized the Treasurer's report for 1 January–31 March 1998. Accepted.

Executive Director Nelson Shaffer distributed his Section Chair and Committee report (Geology and Geography).

Frank Guthrie distributed his 17 April 1998 IAS Academy Foundation Trustees report of selected assets as of 31 March 1998, with some editorial comments on each of the three accounts: the John S. Wright Fund ($5,107,311), the Invested Income Account ($314,652), and the Academy Foundation Fund ($155,546). After some discussion the report was accepted.

Gary Dolph distributed draft Contents pages for *Proceedings* Volume 105, No. 3–4 (1996) and tentative contents for Vol. 106, No. 1–2 (1997). He may have to add two papers to Vol. 106, but both are approved. Should finish this by the end of May. Papers since March have had page charges.

Bill McKnight, Publications Chair, distributed copies of his 6 April 1998 memo and enclosures to the Publication and Executive Committees updating publications issues. After discussion of his misunderstanding with John Gallman of the IU Press and the followup on the Kron-Bolden and Associates' botched production of Vol. 103 of the IAS *Proceedings*, decision was made to "ride it out" on both.

Jim Berry, Newsletter Editor, asked about discontinuing the blue abstract form with the call for papers in the Newsletter, since most everyone now has e-mail and should submit electronically. Discussion showed a continued need for mailed abstracts and that the blue abstract form should be continued in the Newsletter. We print about 1000 copies of each of four issues per year. William Gommel is in charge of obituaries.

Marion Jackson, President-Elect, distributed a list of suggestions on how IAS can become more effective in its mission. Perhaps a speakers' bureau? IAS reviews all papers and rejects some.

Rebecca Dolan distributed lists of her 1998 IAS Committee appointments and the elected Section Chairs. She also provided copies of a new flier on The Indiana Academy of Science with an enclosed application for new memberships, encouraging active use of the flier. Additional copies can be obtained from Nelson Shaffer. She reported Junior Academy things are in good order. To save mailing costs, she also suggested we renew memberships at the Fall meeting.

Gary Dolph moved that the Executive Committee meeting adjourn. Adjourned at 3 PM with IAS Council meeting to begin in 10 minutes.

COUNCIL MEETING

Turkey Run State Park
17 April 1998

President Dolan opened meeting at 3:20 PM. She asked for a rising roll call of members. Council members present: those listed in the Executive Committee meeting minutes, plus Dick Conklin, Jim Curry, William Gommel, Ellen Jacquart, Nils Johansen, Damian Schmelz, and Dan Webster.

After distributing tentative agenda for the Council meeting, Dolan announced the last Council meeting was held at St. Joseph's College, and no minutes are available. Dan Webster moved that agenda be approved. Seconded and passed. Treasurer Frazier summarized budget for 1 January–31 March 1998. Bill McKnight suggested we determine what group determines use of funds. Gary Dolph reported as in Executive committee minutes, but added page charges $10 for members, $35 for non-members. Jim Berry reported 1000 copies of newsletter were being prepared at a cost of $700–800, with the next issue in June including blue line call for papers. Marion Jackson distributed his report, as in Executive Committee minutes. President Dolan distributed the new IAS Brochure which has been mailed to all colleges and departments in Indiana. Dan Webster, Chair of Awards Committee, needs recommendations for new IAS Fellows. Emeritus members were discussed, but don't push this. Ellen Jacquart heads the new Biodiversity/Natural Areas Committee, and was to have a meeting 18 April. Ed Squires, Finance Committee, gave audit report and indicated that it was not clear as to who is bonded. Bill McKnight moved that audit report be accepted. Passed. Holly Oster, Chair, Library, distributed the address of the IAS Homepage as: HTTP://WWW.STATELIB.LIB.IN.US/WWW/IAS/IAS.HTML.

Bill McKnight, Chair of Local Arrangements for the IAS fall meeting at Park Tudor School in Indianapolis, distributed a list of the work to be done for the 29–30 October 1998 meeting. The absolute deadline for receipt of abstracts is Sept. 20, and meal deadline is Oct. 10. They can seat 350 people at a time. He needs referees for the Junior Academy. Any suggestions for enhancing the Fall 1998 meeting at Park Tudor School in Indianapolis should be sent to Bill McKnight.

Richard Conklin, Chair, Nominations Committee, has had no response to the request for nominations included in the March newsletter.

Bill McKnight distributed the IAS Publications list and prices (12/97), and briefly described new books sent to his committee for recommendations: Ferns, Dragonflies, Lake Calumet, and Anatomy of a Woodchuck. The Grants committee will meet in May.

Old Business: Bill McKnight reported present IAS web site is under State control and is not current. We need to have our own web site to show the public what IAS is about and to advertise our books. His students are planning a web site demonstration, but it is not yet available. It is not housed at any one place and there are several places to edit—40–50 a month. Recommend that IAS control our own web site. President Dolan appointed an *ad hoc* committee on web site: Bruce Kingsbery, Holly Oster, Gary Dolph, and Nelson Shaffer.

New Business: Need to be able to renew membership at Fall meeting. See Executive Committee minutes.

There was some discussion of increasing research grants and asking grantees for better accountability, e.g., submitting final report. The grantee does have to send a financial report to Treasurer, but there may not be a final scientific report.

Executive Director announcements: Eric Kavale of the Indiana Geological Survey will give the talk tonight at 8:00 PM on how diurnal lunar tidal action can be read in sedimentary rocks. He will also lead the geology field trip Saturday morning at 9:00 AM to demonstrate his talk tonight. Mike Homoya, Biologist with DNR, will lead the wild flower tour at the same time.

Bill Gommel, IAS Historian and also Necrologist, asked members to let him know of any deaths of IAS members, and also send him obituary clippings.

Nils Johannsen, Chair, Local Arrangements for the Fall 1999 IAS meeting at the University of Southern Indiana, Evansville, announced that the Spring 1999 meeting will be in New Harmony, Indiana.

Damian Schmelz, IAS Coordinator with DNR, said one goal of DNR is to have a State Park within a one-hour drive for anyone in Indiana, and reviewed the progress on the Prophetstown State Park.

Bill Gommel moved that the meeting be adjourned at 5:20 PM.

Robert F. Dale, Secretary

EXECUTIVE COMMITTEE

Park Tudor School (Indianapolis)

18 July 1998

President Dolan called the meeting to order at 9:45 AM. Members present: Rebecca Dolan, President, Robert Dale, Secretary, Gary Dolph, Marion Jackson, Bill McKnight, and Nelson Shaffer.

McKnight started the meeting with an impressive demonstration by two of his Park Tudor students, Yah Anokwa (sophomore) and Mike Mulcahy (senior) on preliminary work on a web page for the IAS.

Dolph moved that we allocate $1,000 from Publications Marketing to set up a web page for IAS. Seconded by Jackson and passed unanimously. This will be demonstrated at the Fall meeting.

Minutes of the 17 April 1998 Executive and Council meetings were accepted with the following corrections and amendments: Page 1, paragraph beginning "Frank Guthrie . . .": Add at end of paragraph "The Executive Committee directed the Finance Committee to reallocate assets to generate more spendible income."; Page 3, top paragraph: Replace "new books" with "prospective manuscripts." Agenda were approved.

Treasurer's report was distributed, but Ed Frazier could not attend meeting and there were no additional comments or questions.

Shaffer handed out breakdown of IAS members as of this date, totalling 827 in all categories. The 1998 *Yearbook* is ready for printing, awaiting bids, two so far of $1538 and $1590. We have sold no advertising so IAS will assume whole cost. Discussion of late dues and inclusion of the respective member's name in the *Yearbook*. Have two new Section Chairs, William Cook in History of Science, and Peter E. Scott in Ecology. Shaffer has sent out IAS member mailing lists to the respective Section Chairs.

Dolph reported Vol. 105 of the *Proceedings* ready, waiting for the index. Vol. 106 (1–2) about ready. He received a thank you letter from Faye Daily, enclosing an obituary for her husband, William Daily, who died 6 July 1998. McKnight attended funeral and will send obituary to Bill Gommel.

Dolan reported on a letter she had received from the Dean of Arts and Sciences at Indiana University. Because of a fund shortage or reallocation, it will be necessary for IU to cancel several programs impacting heavily on IAS affairs. The cancelled programs are the Advance Placement Teachers Workshops in calculus, English, and biology, the annual Science and Math Conference, Science Olympiad State Tournament, the Indiana Junior Academy of Science Symposium, Exploration of Careers in Science, and the South Central Indiana Regional Science and Energy Fair. President Dolan has written the Dean regretting this action. Linda Airey, Franklin College, and Shireen DeSouza, Ball State, will have the Fall Junior Academy of Science program.

Dolan reported Kron-Bolden will pursue $6,000 in small claims court from IAS (because of their botched production of Vol. 103 *Proceedings*). She has contacted a lawyer and the court date of 30 June was postponed. Dolph will send botched copy of Vol. 103 of *Proceedings* to Dolan to give to lawyers. Do we need to retain a lawyer for IAS? Tabled for the Fall meeting.

Dolan is working on an improved IAS award process. There are grants from AAAS for an annual AAAS membership for two high school students (male and female) and two college students (male and female) on presentations at the Fall meeting. She asked Past President and President-Elect to judge. She also distributed a newsletter of the Academy of Science Youth Activities, *Scientific Notations*, which needs a new editor.

McKnight needs by the first week in September the needs for each Section. He is also getting the Speaker of the Year, and will appreciate any help he can get for the Fall meeting.

Dolph moved for adjournment at 11:30, thanking Bill McKnight for the coffee, juice, fruit and doughnuts. Passed unanimously.

Robert F. Dale, Secretary

EXECUTIVE COMMITTEE MEETING

Park Tudor School (Indianapolis)
29 October 1998

President Dolan opened the meeting at 1:10 PM and distributed tentative agenda. Members and guests present: James Berry, Rebecca Dolan, Robert Dale, Gary Dolph, James Haddock, Marion Jackson, Duvall Jones, Bill McKnight, and Nelson Shaffer.

Shaffer distributed copies of minutes he had reconstructed from his tape of the proceedings of the 30 October 1997 IAS Executive Committee and Council meetings at St. Joseph's College, (Rensselaer) and the 31 October 1997 IAS General Business meeting, as well as the minutes by Secretary Dale of the IAS Executive Committee meeting 18 July 1998 at Park Tudor School. Haddock moved acceptance of the 1997 minutes pending further reading, second by Dolph. Jackson moved acceptance of the 18 July 1998 minutes with the correction of the History of Science Section Chair's name from William to Donald J. Cook. Seconded by Dolph.

McKnight distributed copies of the Treasurer's report and said Treasurer Frazier will be here tomorrow. McKnight read the Treasurer's account summary comments on the back of page 1 of his report.

Shaffer distributed copies of IAS Membership numbers, totalling 855 in October 1998 compared to 838 in 1997. He also distributed copies of a 28 Sept 1998 letter from Lynn Elfner, CEO of the Ohio Academy of Science, asking IAS endorsement of a $1 million proposal to the National Science Foundation on Project Parent S.O.U.P.—Science Opportunities Unlimited for Parents. The preliminary proposal is available on the Academy's website: http://www.ohiosci.org/soup.htm or by FAX or mail. Dolph moved that the Executive Director draft a letter supporting the request. Second by Jackson. Jackson asked about the decrease in Emeritus members (56 to 50) with discussion following.

Dolph distributed copies of tentative content pages of IAS *Proceedings*, Vol. 106, No. 1–2 (1997) and No. 3–4 (1997) and Vol. 107, No. 1–2 (1998) with comments.

Berry asked members to send something to print in the newsletter. Discussion and suggestions followed.

Jackson asked if there were written instructions to Section Chairs on encouraging members to present papers and on the preparation of abstracts for the meeting program. McKnight, on the basis of many problems encountered organizing the program for this year's meeting, had prepared a page of instructions for the authors, section chairs, and compilers (this year McKnight) to decrease the nightmare—use E-mail or disc and obey deadlines!

Jackson also asked about a letter to potential IAS members. Dolan has flier (distributed at Spring meeting) which Shaffer will send to Science Department Chairs and Librarians.

President Dolan has received a letter from the Ohio Academy of Science asking for support for a National Institute for the Environment. The Indianapolis Public Schools are interested in the Junior Academy. Committee updates will be discussed in the following Council meeting. On unfinished business, Dolan reported that since there have been embarassing occasions of no followup on notifying recipients of the awards given by the IAS, she is sending them out. She also wants our web-site developed and will appoint an *ad-hoc* committee for this. Kron-Bolden filed a law suit for $7,000 (for low quality proofs of a *Proceedings* volume in 1994) with a court date of 27 September 1998. We hired a lawyer and supplied him with discarded copies of the volume for evidence. Kron-Bolden cancelled the court date.

Under new business, Jones distributed a memo proposing an Education Symposium in December 1999 and recommending that IAS allocate $2,000 for related expenses. The program would be similar to "Science Education at the Crossroads" in 1988. The Indiana State Board of Education is developing a consensus on this. Haddock moved development of steering committee to help plan this symposium.

Haddock moved adjournment at 3:00 PM.

COUNCIL MEETING

Park Tudor School (Indianapolis)
29 October 1998

President Dolan called the meeting to order at 3:15 PM and distributed tentative agenda. Members and guests present: Linda Airey, James Bandoli, James Berry, Richard Conklin, Robert Dale, David Daniel, Gary Dolph, William Gommel, Frank Guthrie, James Haddock, Ellen Jacquart, Marion Jackson, Duvall Jones, Bill McKnight, Holly Oster, Damian Schmelz, Peter Scott, Nelson Shaffer, Daniel Webster, Terry West, and Robert Wolf.

The minutes of the Council (and Executive Committee) Meeting on 17 April 1998 at Turkey Run State Park had been mailed to Council members earlier. Webster moved approval of the minutes. Passed. Agenda approved by acclaim.

Treasurer's report was distributed by Shaffer, who pointed out that 75% of the research proposals were funded.

Reports by Executive Director Shaffer, *Proceedings* Editor Dolph, and Newsletter Editor Berry similar to those in Executive committee minutes.

Jackson stressed membership and informed the Council there would be a Budget meeting at Butler University on 5 December 1998 to determine the 1999 budget. Budget requests should be sent to Jackson or Dolan.

Dolan reviewed the Kron-Bolden suit and asked if IAS should retain a lawyer. (McKnight, at the IAS Publications Committee meeting at 10:30 AM this morning, had distributed the Kron-Bolden Chronology report as a part of his agenda and provided copies to interested Council members.) Gommel asked if the Indiana State Attorney General could help on such occasional problems. Dolan will appoint an *ad hoc* committee to study and make recommendation on IAS retaining a lawyer.

Damian Schmelz distributed copies of his Natural Resources Commission report of 29 October 1998.

Gene Kritsky did not attend meeting but provided copies of his report on the meeting of the National Association of Academies of Science (NAAS) in Philadelphia on 10–14 February 1998 in association with the AAAS meetings. His report included a note that he will complete his 3-year appointment as IAS Representative to the AAAS at next year's meeting at Anaheim, California, and will not be asking for a third appointment to this post. He also included a proposal for the appointment of an Academy Liaison to the National Council for Science Education. Dolan asked anyone interested in being the IAS representative to the NAAS meetings, beginning in 2000, to let her or Jackson know.

Gommel, Historian, suggested IAS members send a copy of their histories to either himself or Holly Oster, Archivist, to have on file, and also to send obituaries of any friend or associate known to have been a member of IAS. He also read a tentative list of member deaths reported since the last annual meeting for confirmation and reading at the annual meeting tomorrow.

Guthrie distributed copies of the Academy Foundation Report 28 October 1998 showing a total market value for all funds of $6,030,754 with an estimated annual income of $135,865. They will continue to monitor assets and income to ensure that the IAS can maintain growth prospects while increasing support for research projects.

Oster distributed a 1998 report on changes and holdings in the John Sheppard Wright Memorial Library. This included an increase of 120 volumes to 12,473 as well as the respective numbers of pamphlets, maps, microfiche, data disks, and posters. There were 503 inter-library loans, 1100 copies of *Proceedings* Vol. 105 (3–4) received from the printer and 640 mailed to eligible Academy members. State funds for printing Vol. 107 were received and forwarded the IAS Treasurer. The IAS state budget request for $17,622 in the 1999–2000 biennium was prepared by the Sate Library and submitted to the State Budget Agency.

Airey reported a decrease in Junior Academy participation.

Jones distributed a 24 October 1998 report from the IAS Youth Activities Committee, including minutes from their 28 May 1998 meeting. The number of students and mentors receiving support for secondary student science research grants has increased from 21 students receiving a total of $1961 from IAS and $1700 from AAAS in 1997 to $3500 from IAS and an expected $1700 again from AAAS in 1998. Funding and the number of mentors has not kept up with the increase in grant requests.

Daniell confirmed that the Spring 1999 meeting will be at New Harmony and the Fall 1999 meeting at the University of Southern Indiana, but the sites for 2000 have not yet been determined.

Jacquart reported the Biodiversity and Natural Areas Committee was surveying the available data being monitored in the state by DNR, IAS and other organizations, with a committee meeting tonight from 7:00–9:00 PM.

Conklin presented election results: Ruth Howes for President-Elect, Robert Howe for Research Committee, and, to correct an omission on the ballot (and in the 1998 Yearbook), Stanley Burden on the Academy Foundation. Approved. Conklin also reported there were fewer ballots returned this year, only 167, compared to 207 last year and 300 two years ago.

Webster distributed the 24 October 1998 report of the Awards Committee, electing for Distinguished Scholar, Ernest Roy Davidson, for Fellow, John Castrale and Edward Frazier, and for Emeritus Member, Frank Guthrie. Webster moved that these recommended members be approved for the indicated awards, second by Haddock and passed unanimously by Council. Fellows and Emeritus member have to be approved by the total membership at the Annual Meeting tomorrow.

A resolution to be introduced at the annual meeting was drafted and read by Shaffer, thanking Bill McKnight and Headmaster Bruce Galbraith for the excellent facilities and many courtesies extended to IAS at Park Tudor School. Unanimously approved on motion by Shaffer and second by Gommel.

Jones distributed his 27 October 1998 proposal for a 1999 Education Symposium to Council members. See Executive Committee minutes.

McKnight distributed copies of his corrected "Rules for Submission of Abstracts" to Council members and indicated that these would be published in the newsletter and also provided to Section Chairs tomorrow morning.

Gommel moved for adjournment at 5:05 PM.

GENERAL BUSINESS MEETING

Park Tudor School
30 October 1998

President Rebecca Dolan opened the 114th IAS Annual Meeting at 1:01 PM. She introduced Bruce W. Galbraith, Headmaster of Park Tudor School, who welcomed the Indiana Academy of Science members to the campus and gave a brief background of the private school which educates students from three years of age through high school. Most classes had been dismissed, and the students and faculty were also in attendance. President Dolan read a Resolution thanking Park Tudor School officials, and especially Bill McKnight, for hosting this 114th IAS annual meeting. Resolution passed unanimously.

William Gommel, Historian/Necrologist, read the names of the following IAS members with year of death: Frank N. Young, 1998; George B. Craig, 1887; William A. Daily, 1998; Robert C. Pittenger, 1998; Newton G. Sprague, 1998; Joseph S. Ingraham, 1997; Raymond E. Girton, 1997; James R. Rees, 1998; James P. Holland, 1998. Members then stood for a moment of silence in honor of the departed members for their services to the Academy and the world of science. Gommel then encouraged members to send their resumes to him, Holly Oster, or Executive Director Shaffer for file, and also any obituaries for departed members to him, Shaffer or Newsletter Editor Berry.

Dan Webster read the recommendations of the Awards Committee: Ernest Roy Davidson for Distinguished Scholar. Webster moved, second by Haddock, passed unanimously. For IAS Fellow: John Castrale and Edward L. Frazier. For Emeritus member: Frank A. Guthrie. Webster moved, second by Haddock, passed unanimously.

Gary Dolph, *Proceedings* Editor, reported he has enough papers for Vol. 106 (1997) and has some for Vol. 107 (1998) and called for more papers. While problems with printer have caused delays in the past, don't worry about time-sensitive papers, we'll rush them into Vol. 107 (1–2) (1998).

Richard Conklin announced election results: Ruth Howes for President-Elect, Robert Howe for Research Committee. Also, Stanley Burden was omitted from the ballot (and the 1998 Yearbook) as a Trustee on the Academy Foundation, which requires a vote from the membership. Passed unanimously.

On behalf of the Indiana Academy of Science Executive Committee, Executive Director Shaffer thanked President Rebecca Dolan for her excellent stewardship the past year, which included preparation of a membership brochure among many other enlighteed activities.

President Dolan passed the gavel over to incoming President Marion Jackson, who adjourned the meeting at 1:25 PM.

After a five minute break, John Schutt introduced Uwe Hansen, Speaker of the Year, who gave an inspiring talk and demonstration on the use of physics (frequency) in music, applicable to almost any education level.

Robert F. Dale, Secretary

EXECUTIVE COMMITTEE

Butler University
5 December 1998

President Rebecca Dolan opened the Executive Committee meeting at 9:45 AM. Members present: Linda Airey, Clare Chatot, Robert Dale, David Daniell, Shireen DeSouza, Rebecca Dolan, Gary Dolph, Frank Guthrie, Ruth Howes, Marion Jackson, Ellen Jacquart, Nils Johansen, Duvall Jones, Bill McKnight, Holly Oster, and Nelson Shaffer. President Dolan indicated we had one piece of unfinished business to handle before turning the meeting over to incoming President Jackson for the Budget Committee meeting. She moved that the IAS Treasurer be authorized to sign 1999 Letters of Agreement for the Editor of the *Proceedings*, Gary Dolph; for the Executive Director, Nelson Shaffer; and Publications Managing Editor, Bill McKnight. Jackson seconded and motion passed unanimously.

Jackson read a thank you letter he had written to Rebecca Dolan for her excellent stewardship as President IAS the past year. He will give letter to Jim Berry for publication in the IAS newsletter.

Shaffer reported he had sent out dues notices to members and had closed the books on 1998.

Dolph moved for adjournment of the Executive Committee meeting. Shaffer seconded at 9:54 AM.

BUDGET COMMITTEE

Butler University
5 December 1998

President Marion Jackson opened the meeting at 9:55 AM. Members present: Same as above.

Shaffer moved to accept budget as submitted by Ed Frazier, Treasurer, showing $35,610 projected income for 1999 budget with rundown of expenses, restricted fund revenues and expenses, and foundation invested income account. Seconded by Dolan. (Budget passed after the following discussions and modifications.)

On a question from President-Elect Howes to Oster on the $3000 request for binding in the Library Operations expenses, Oster reviewed some of her activities with the State Library, including that they receive not only the Indiana Academy of Science *Proceedings*, but also those from all other states and many foreign countries. Chatot asked Jacquart about the $150 request in the operating fund expenses for the data base collection. Jacquart moved to delete the $150 request and will investigate seeking IAS research funds for this. Second by Chatot and passed unanimously. Jacquart then moved that $1000 be included in the Biological Survey for an education publication on non-native invasive plants. Second by Chatot and approved on a 9–2 vote.

Jones pointed out the Indiana Junior Academy of Science proposed 1999 budget in the honorarium for sponsoring teachers should be $200, not $100, so that the Junior Academy total should be $6575, not $6475. This brings total operating fund expenses to $45,100 and the revenues over expenses to $9,490.

McKnight brought up (apparently for the third year) the lack of a policy on how the Past President and Life Member funds should be used. Jackson appointed McKnight, Jones, Guthrie, Howes, and Treasurer Frazier as an *ad hoc* committee to make such policy recommendation.

Dolph indicated that 1999 is the first year we will have page charges for the *Proceedings*, and that these will bring in about $2,000 more than shown in the budget. This brings the total income from the Proceedings to $10,200 (instead of $8,200), and accordingly the total restricted funds revenues to $128,250 and the revenues over expenses to $30,450, respectively.

McKnight discussed the need for our own IAS home page, as demonstrated at the 18 July 1998 Executive Committee meeting (see 18 December 1998 minutes). The present home page at the State Library just is not adequate and cannot be kept up-to-date. Without close monitoring of an IAS home page Howes fears material may appear on the website which could reflect badly on IAS. McKnight needs website for sales of publications. Shaffer, representing Treasurer Frazier, indicated he was reluctant to add a separate item on this at this time.

Chatot moved that the restricted fund revenues and expenses be approved. Seconded by Dolph and passed as corrected.

Chatot moved to accept entire budget. Second by Howes and passed unanimously.

Academy membership brochures were distributed to members present, and Shaffer will send them to College Science Departments and Libraries.

President Jackson ended by asking for input on any IAS activity not voiced here.

Dolan moved for adjournment at 12:40 PM, seconded by Shaffer and passed unanimously.

Robert F. Dale, Secretary

MINUTES OF THE MEETINGS OF THE INDIANA ACADEMY OF SCIENCE 1999

EXECUTIVE COMMITTEE

New Harmony, Indiana
16 April 1999

President Marion Jackson opened the Executive Committee meeting at 1:15 PM in the New Harmony Inn.

Members present: James Berry, Robert Dale, Rebecca Dolan, Edward Frazier, Ruth Howes, Marion Jackson, Holly Oster, and Nelson Shaffer.

Howes moved that the 5 December 1998 Executive Committee meeting minutes be approved as printed. Passed.

Jackson moved that the 29 October 1998 Executive Committee meeting minutes be approved as printed. Passed.

Frazier distributed and reviewed the budget and account summary from 1 January to 31 March 1999, suggesting that we think about the use of the Welch funds on plant research.

Dolan informed the committee that the Kron-Bolden case has been settled for $3000.

After some discussion on determining future IAS meeting dates well in advance, Howes moved that we establish next year's budget meeting on 4 December 1999. Passed.

Shaffer said Frank Guthrie could not attend this meeting but had informed him that, with the merger of Bank One and NBD it may be necessary to diversify the IAS portfolio of about $5 million. No action is required at this time.

Shaffer distributed his report on the number of IAS members in each category, totaling 824 as of 14 April 1999. He is cutting off membership and starting on the Yearbook. He has had problems getting Section Chairs and Committee Chairs established. The *Proceedings* editor could not be here, but Vol. 106, No. 1–2 (1997) are printed. However, Oster does not yet have them for mailing. Shaffer distributed the contents page for Vol. 106, No. 3–4 (1997) with progress indicated on each paper. Dolph hopes to mail this issue to the printer at Bloomington by 15 May.

Berry reported it is still difficult to get information for the newsletter, and asked if it were still necessary to use the blue line page for abstracts, which has to be printed separately at a cost of $200-300. Committee agreed to no blue line insert in newsletter.

Jackson reported for Bill Gommel, IAS Historian, that three long-term IAS members, Lois Burton, Alan Horowitz, and Howard Michaud, have died since the Fall 1998 meeting.

Marion Jackson reported that *The Natural Heritage of Indiana*, first printing, is sold out of stock at IU Press. However, Bill McKnight, Publications Chair of IAS, currently has about 175 copies remaining. McKnight recently sold *circa* 50 copies to Purdue University NW for use as a college text. Jackson also reported that IU Press and educators around Indiana have shown interest in modifying *The Natural Heritage of Indiana* for use as a high school text.

Jackson also reported for McKnight that Dr. Sherman Minton's *Amphibians and Reptiles of Indiana* is scheduled for publication as soon as minor details are corrected. Jim Curry's *Dragonflies of Indiana* should be completed by this fall. There is interest in a possible publication of correspondence between Dr. Charles Dean and Floyd Swink and others regarding botanical lore of Indiana.

Rebecca Dolan distributed a report from David Daniell for the Programs and Invitations Committee that Indiana University East at Richmond had invited the IAS to have their Spring and Fall 2000 meetings there. After some discussion Frazier moved that we recommend this to the Council. Howe seconded and passed.

Shaffer read a 15 April 1999 letter from Ellen Jacquart, Chair of the Biodiversity and Natural Areas Committee, providing the agenda for their meeting, unfortunately being held today in Indianapolis.

Jackson reported that the Indianapolis Parks and Recreation Dept. had asked for approval to use our IAS logo on some of their publications in which they have used information or materials from IAS. Permission was granted. He also reported on a letter received from Alton Lindsey.

The *ad hoc* committee concerning the IAS Web Site will be convened by Bill McKnight this summer. Dr. Tim Mulkey of ISU has been added to this committee to take advantage of his computer expertise.

Dolan circulated several special science articles from the *Sun Sentinel* of Fort Lauderdale, Florida suggesting that IAS consider preparing something similar for local newspapers.

Meeting adjourned at 3:05 PM, Council Meeting in 10 minutes.

COUNCIL MEETING
New Harmony, Indiana
16 April 1999

President Jackson opened the IAS Council meeting at 3:20 PM.

Members and guests present: James Bandoli, James Berry, Richard Conklin, Robert Dale, Rebecca Dolan, Edward Frazier, Ruth Howes, Marion Jackson, Blake Janutolo, Nils Johansen, Duvall Jones, Holly Oster, Damian Schmelz, Nelson Shaffer, Dan Webster, and Howard Youse.

Shaffer distributed minutes of the 29 October 1998 Council meeting. Minutes were approved on motion by Webster and second by Schmelz.

Agenda were approved, and Frazier distributed and discussed budget. He also distributed the report of the Finance Committee, Robert Waltz, Chair, which showed the 1998 Year End Financial Report to be a fair and accurate record. Frazier moved, Youse seconded, to accept report. Unanimously approved.

Shaffer presented the IAS member count, indicating that a number of committee members have not paid 1999 dues. He also presented Dolph's report (See Executive Comittee minutes).

Berry reported next newsletter in June 1999 will be on candidates for 2000, and will not include the blue line abstract form for the Fall meeting.

Howes informed Council that the Budget Committee will meet 4 December 1999 to approve 2000 budget.

Jackson reported for Gommel and Indiana Parks and Recreation Dept., as in the Executive Committee minutes.

Schmelz reported on plans of Indiana Natural Resources Commission which has hired the firm that built the Holocaust building in Washington, D.C. to build IMAX theatre to show history of geology, including a limestone quarry. There will also be field trips to Lake Michigan in May, to Pokagan to study aftermath of deer hunt, and concern that the Gypsy moth is moving south from Michigan and west from Ohio.

Jackson reported Gene Kritsky has asked to be relieved of his appointed position as IAS Representative to AAAS, and that Richard Kjonaas has agreed to serve in this position.

Jackson gave McKnight's report, as in the Executive Committee minutes.

Jones reported for youth activities. They have had one application for a High School Research Grant and are going ahead with the Symposium on Science Education in cooperation with the Hoosier Association of Science Teachers, Inc. (HASTI) convention to be held 9–11 February 2000. They are looking for a speaker on involving students in biology K-12, and will have three programs: Assessment at the state level, Teacher performance, and Student assessment. IAS will have a booth (3000–4000 attendance expected).

Conklin reported no nominees yet, need input.

Webster needs recommendations for awards: Distinguished Scholar, Special Service to Academy, and Fellows.

Dolan brought the IU East invitation for the 2000 IAS meetings to the floor and indicated that the Executive Committee recommends approval. She moved, and Webster seconded, that the Council approve IU East at Richmond for the IAS meeting in 2000. Passed.

Jackson said the Budget Committee meeting will be on 4 December 1999, and that Bill McKnight is on the *ad hoc* web site committee.

Shaffer reported for Frank Guthrie (see Executive Committee minutes) and for Claire Chatot: one research grant given for high schools and 30 for universities.

Under New Business, Webster asked that papers submitted to the annual meeting should be assigned to the proper section. He had surveyed the papers presented the past few years and believes that many papers submitted to Section Chairs should be in another Section, e.g., many papers in Ecology should be in either Zoology or Botany. After considerable discussion, the Local Arrangements Committee of the University of Southern Indiana (Bandoli and Johansen present) offered to receive the abstracts directly for the advantage of more timely receipt of abstracts. Howes moved that the Local Arrangements Committee be authorized to solicit and handle this year's abstracts directly and arrange the program, clearing instructions with Shaffer and Berry (June newsletter) to ensure that Section Heads and authors are properly informed of the procedures. Second by Youse and passed.

Shaffer thanked the Local Arrangements Committee for the excellent facilities provided for this Spring meeting.

Meeting adjourned at 5:10 PM.

Respectfully submitted,
Robert F. Dale, Secretary

EXECUTIVE COMMITTEE
Butler University
24 July 1999

President Marion Jackson opened meeting in Room 300 of Gallahue Hall at 9:15 AM.

Members present: James Berry, Robert Dale, Rebecca Dolan, Gary Dolph, Edward Frazier, Ruth Howes, Marion Jackson, Nils Johansen, Bill McKnight, and Nelson Shaffer.

Howes moved that the minutes be approved. Seconded by Dolan and motion passed.

Shaffer reported that CINERGY wants to be a corporate member of IAS and asked if copies of the History of the Indiana Academy of Science were available for supplying copies to corporate members. McKnight said he has about 500 copies, but that we provide more benefits to corporate members than the membership dues warrant. This led to a discussion of corporate members versus sponsors, which would require a change in our constitution. Howes moved that Shaffer be authorized to look into the legal questions required for corporate sponsors or redefine corporate member. Seconded by Dolan. In following discussion Howes suggested this would require a 5-year plan as to what we would do with sponsor donations, recognizing that IAS is the only state voice for science. Motion passed unanimously.

Shaffer reported there are now 886 members, including life members. The 1999 Yearbook cost $500 more than budgeted. We need to line up meeting dates beyond 2000.

McKnight reported we may collaborate with the Shirley Hinds Environmental Fund on the Charles Dean–Swink publication.

Curry's *Dragonflies of Indiana* is out for review and he hopes to get reviews back by October. We do not have the Walsworth Printing report yet on Minton's *Amphibians and Reptiles of Indiana. Plants of Chicago* (4 years ago) by Swink has been well received.

Dolph reported Vol. 106, Nos. 3–4 galley proofs should be out to authors before October. He described problems with manuscripts and only has about half enough papers for Vol. 107, Nos. 1–2.

Berry suggested that the Section Chairs should have been listed in the last newsletter, but he couldn't find a complete list. The third issue of the newsletter will be out in August with election and registration materials, and the fourth issue will be mailed after the Fall meeting.

Johansen reported that the Bandoli June 1999 e-mail letter on IAS new abstract procedures, sent to Section Chairmen, has been reproduced by them for their section members and seems to be working well, abstracts to be sent to jhbandol@usi.edu which has a positive website.

McKnight asked what to do about the IAS website. All he wants to do with the website is to advertise and sell publications, i.e., if we want a Jr. IAS page someone else can do this. He said that "IAS" is taken but "inacadsci" is available. Howes moved to authorize Bill to get this name. Seconded by Dolan and passed.

Jackson passed around a description of the Indiana State History Museum and discussed the need for space in it for IAS. In the discussion it was suggested we have a display in a 5 × 5 kiosk, and that we would have to keep it current. More than half of the ISHM board members are either IAS members or sympathizers.

Dolan had talked with Ellen Jacquart, Chairman of the Biological Survey Committee (now called Biodiversity and Natural Areas, BNA), who indicated that they would like to meet with the Executive Committee before the Fall meeting with regard to getting more support for their work. They would need about three hours to brief the Executive Committee. After some discussion, Dolan will propose to Jacquart that the BNA and Executive Committees meet at Butler at 9:00 AM on 7 October 1999.

Frazier distributed and discussed the IAS Budget Comparison 1 January to 31 March 1999 and the IAS Account Summary for the year (1999) to date.

Dolan pointed out that the bulk of the money in the Wright Fund is controlled by the Trustees and is earning only 1.4%. What are the constraints on getting more research funds? McKnight said that the Wright Fund has grown from about $2 million in 1991 to $6 million in 1998, but that in the same period the research funds available for IAS to distribute to researchers in Indiana have only grown from $80,000 to $90,000 (probably less than the Bank One fee for managing the Wright Fund). After discussion on getting more real money for research purposes, the Executive Committee agreed to meet again with the Trustees and, if possible, a Bank One representative at 9:00 AM on 26 August 1999 to determine what changes can be made to get more research funds now, President Jackson to issue invitation to Trustees and Bank One.

McKnight moved to adjourn meeting at 12:30 PM. Passed.

Respectfully Submitted,
Robert F. Dale, Secretary

EXECUTIVE COMMITTEE
with Trustees of the IAS

Butler University
21 September 1999

President Marion Jackson opened meeting in Room 300 of Gallahue Hall at 9:35 AM, indicating the main reason for this meeting was to discuss with the Trustees the potential for getting more resources from the Trustees for support of science research grants.

Members present: Stan Burden (Trustee), Robert Dale, Rebecca Dolan, Gary Dolph, Edward Frazier (*ex officio* Trustee), Frank Guthrie (Chair Trustee), Ruth Howes, Marion Jackson, Duvall Jones, Holly Oster, and Nelson Shaffer.

Frank Guthrie summarized his letter of 1 September 1999, sent out with Jackson's 3 September 1999 memo announcement of this meeting, indicating that, while Bank One had indicated there would be a 35% fee discount, the trust maintenance fee actually has increased $3400 to $25,100. The Trustees are considering moving the IAS Academy Foundation account to Merrill-Lynch where the annual fee will be $8000–10,000. Guthrie distributed a listing of the three accounts in the Trust Funds of the Indiana Academy of Science, which as of 31 July 1999 totaled $6,087,559.72. The Wright Fund comprises $5,508,197.74 of this total. We can't spend the principal in the Wright Fund but we can use the earnings to support research grants, publication of *Proceedings* of the IAS, and in the past, monographs.

Dolan distributed copies of selected pages of *History of the Indiana Academy of Science, 1885–1984* (Daily and Daily, 1984), calling attention to Fig. 38, p. 145, with excerpts from the John S. Wright will on supporting IAS research.

Howes asked who makes decisions on use of earnings? Burden said McKnight got funding for the butterflies book publication. Dolan asked how McKnight got the money for the publication? Guthrie stated the Trustees have responsibility for safeguarding the trust funds and feel they have to reserve some of the income. The Council determines policy, the Chairman of the committees (including Research Grants) contacts his members on needs and brings these to the Executive Committee. This does not include the operational funds budget of about $35,000 from dues.

Nelson indicated we're holding steady with membership so there is not much change in the operational budget.

Dolan reported science research projects supported by IAS are usually limited to $2000. How can we increase this?

Howes distributed a two-page statement she had prepared on Projects for the Indiana Academy of Science, including several Possible Actions under each of three headings, Research, Science Education, and Science and the State. She pointed out that IAS has the responsibility to guide science research and education in Indiana, grades K-16.

Dolan distributed a memo from Clare Chatot (Chair, Research Grants Committee, not present) 9 September 1999, listing the numbers and dollar amounts for IAS research grants funded and received from 1992 to Spring 1999. Generally between 40–50 research grants are funded each year at a total of $35–40,000. Chatot believes a reasonable amount which could be consistently awarded would be $50–60,000, which may not increase the percentage of grants funded but would increase the funds per grant for proposals of appropriate quality.

Jones passed out a page with Table 1 showing the Membership and Funding for the Precollege Research Program, from 1989 to 1999. While the number of student grants increased from 11 in 1989 to 24 in 1997-98 the number of school-based research mentors showed little change with a nucleus of 6–8 persons with long term commitments. Funds have ranged from about $1800–4000 a year with $1500 of this coming from AAAS. (See Science Education in Howes 21 September 1999 report).

Dolan reminded members that the Biodiversity and Natural Areas Committee will inform the Executive Committee about its needs for a data base at 9:00 AM on 7 October 1999 here at Butler.

Guthrie asked if research grant proposals are reviewed for quality and promise? Howes said "yes, we have an elected committee to review research grant proposals." Jackson asked what we can expect in the way of financial support for science research the next three years? Guthrie indicated that the Trustees are not sitting on $6,000,000, only the invested income of about $400,000.

Dolan asked if we have a policy on how much more the corpus grows, $10 million? Guthrie replied that we cannot spend the Wright Fund account, only the income, so yes, it could grow to $10 million. Burden asked if the Executive Committee could put together a 5-year plan as to what the research people have in mind? Following discussion showed the need for more accountability on what has been supported to convince Trustees of the need to increase financial support, e.g., support of undergraduate research, especially with credit given to Academy for partial support for published research. Shaffer indicated that recently we have had fewer people coming to IAS for research support, and that we should be concerned with this discouragement of research rather than encouraging it. Howes suggested a letter to committee chairs asking for written report on monetary support needs and justification for Executive Committee meeting at the Fall meeting at Evansville. Since we already have a full plate at the Fall meeting Nelson suggested we have it after the Budget meeting at Butler University on 4 December 1999.

Jackson and Howes will compose a letter calling for a retreat at a state park all day on 19 February 2000, and Dolan will order lunch.

Jackson commended the Trustees for their copies of e-mails informing us of the change from Bank One to Merrill-Lynch, thanked them and the members for attending this important discussion, and closed the meeting at 11:50 AM.

Respectfully submitted,
Robert F. Dale, Secretary

EXECUTIVE COMMITTEE
meeting with
Committee on Biodiversity and Natural Areas
Butler University
7 October 1999

President Marion Jackson opened the meeting at 9:08 AM in Room 300 of Gallahue Hall, asked members to introduce themselves, and briefly described the reason for this meeting—to learn what the BNA committee is proposing—and our 21 September meeting with the IAS Trustees regarding the potential for getting more resources for support of science research grants in Indiana.

Members present: Robert Dale, Rebecca Dolan, Gary Dolph, Ruth Howes, and Marion Jackson of IAS Executive Committee, and Ron Hellenthal, Michael Homoya, Ellen Jacquart (Chair), Paul Rothrock, Donald Ruch, Thomas Simon, and Robert Waltz of the IAS Biodiversity and Natural Areas Committee.

Jackson noted that we had not approved the minutes of our Executive Committee meetings of 24 July and 21 September 1999, and asked if there were any corrections or additions to either. There being none the minutes were approved.

Jackson then distributed a letter that he and Howes had drafted to the Executive Committee and committee chairs regarding the retreat planned for 19 February 2000. He also read a letter from Damian Schmelz referring to the 13 September 1999 e-mail from Alicia Stewart of the Indiana State Museum, asking for suggestions of Indiana scientists who have made significant contributions to the state for the history museum. One suggestion was David Starr Jordan.

Jacquart introduced the reason for this briefing by the BNA Committee and distributed a flier they had prepared on *Invasive Plants in Indiana*.

Hellenthal (entomologist at Notre Dame) led off the BNA briefing by distributing copies of the slides discussed in his following presentation and his report to the Biodiversity and Natural Area Committee on *A Proposed Information Model for the Indiana Biological Survey*. There is little or no transfer of biological survey data between disciplines, and often these survey data have been gathered at tremendous cost. A number of meetings have been held, starting in 1989, to discuss natural history data standards with the final draft of the information model (distributed above) prepared in April 1999 and adopted by the IAS BNA committee.

Simon continued the briefing, describing the history of the Indiana Biological Survey starting with David Starr Jordan in the late 1800's. It was a rather sad commentary on administrative handling of the various biological collections in Indiana, ending with a suggestion for a Board of the Indiana Biological Survey, overseeing a requested budget of $12,000 for infra-structure competitive grants, $2000 for for data base support, $5000 for publication of a newsletter, and $1000 for logo, printing, web page and miscellaneous. Considerable discussion.

Howes questioned advisability of IBS going it alone without associating with IAS, and the impossibility of the $20,000 budget this year. Also, this does not include support for the model described by Hellenthal. But BNA should come to the budget meeting with a $5000 request and a 2–3 page justification and we will consider it.

Jacquart said the biological sections of IAS will come to a summary presentation of these two BNA presentations at 11:00 AM Friday, 5 November (Fall meeting) to drum up support, and that they will come to the budget meeting 4 December 1999. Dale asked why the Geology and Geography section was not included in the joint BNA presentation at 11 AM since this now includes the former Soil and Atmospheric Science section, and these environmental sections are certainly involved with the suggested information model. Ruch indicated that the Fall program is undoubtedly printed by now but he will contact the local arrangements committee to see what can be done. Ecology also is involved but that section already has too many papers to be presented to include that section in the 11 AM joint session.

In response to BNA criticism of *Proceedings* lag in publication, Dolph said that although the volumes are behind (Vol. 106 (1997) will be out later this month or November 1999), the publication of the research papers is fairly current and mainly controlled by the condition of the original manuscript and the promptness of the two reviews. In fact, he has not published any IAS minutes in the last volumes of the *Proceedings*, trying to get the publication of research manuscripts up-to-date. He has about 60 pages of Minutes to publish which may take almost a volume, and this may be something to discuss at our February retreat.

Howes asked how the BNA documents that this proposed information model is good research, through reviews? Jacquart indicated BNA would work on this.

Howes closed the meeting at 11:35 AM, since Jackson had to leave earlier.

Respectfully submitted,
Robert F. Dale, Secretary

EXECUTIVE COMMITTEE

University of Southern Indiana
4 November 1999

President Marion Jackson opened the meeting at 1:05 PM in Room 206 University Center, USI.

Members present: Jim Berry, Robert Dale, Rebecca Dolan, Edward Frazier, Frank Guthrie, Ruth Howes, Marion Jackson, Duvall Jones, Bill McKnight, Holly Oster, John Robert Schutt, and Nelson Shaffer.

The minutes of the Executive Committee meeting with the IAS Biodiversity and Natural Areas

(BNA) Committee on 7 October 1999 at Butler University were approved.

The tentative agenda for this meeting were approved.

Frazier distributed the IAS Budget Comparison and Account Summary for 1 January–31 October 1999. He reviewed the budget, reported that there were 167 members preregistered for the Fall meeting, and that IAS funds in the money market were bringing a 4.5% return.

Shaffer distributed a report on the number of IAS members in the various categories for each of the years, 1996–1999, totaling 908 in 1999, up from 855 in 1998 but down from 1046 in 1996. He also reported the deaths of five active members, but there may be others recognized in the necrology service tomorrow.

McKnight reported that Gary Dolph does not want to continue his editorship of the *Proceedings* of the IAS, and that an announcement will be prepared for the newsletter indicating the vacancy. McKnight said Gary had done a great job with the *Proceedings* for the last nine years.

Shaffer asked that Gary prepare a budget request for the 4 December meeting at Butler.

Howes asked committee chairpersons to contact her on members they would like appointed to their committees.

Jackson briefly reviewed the progress made in the special Executive Committee meetings on 21 September with the Trustees and on 7 October with the BNA committee, both at Butler. He reported that Richard A. Kjonaas, Dept. of Chemistry, Indiana State University, is now the IAS representative to AAAS, succeeding Gene Kritsky. He also will recommend Gary Dolph for the service award.

McKnight reported on progress in publications, the galley proof of *Amphibians and Reptiles in Indiana* may be ready in early December 1999.

Jones distributed the 1999 IAS Report of Youth Activities Committee, which contained the number of research clubs, student grants, and mentors, as well as funds requested and provided from 1989 to 1999. A major problem is the decrease of high school mentors to encourage student research science projects. The maximum given a student is $250, and total grants usually range between $2000–4000, with $1500 of this coming from the AAAS. He is working on recognition of presenters at the annual meeting and handed out score sheets to be used tomorrow, one for each section. Howes said we need more aggressive programs to encourage recruitment of students into science. Jones replied that NSF cut off funds for high school student research several years ago. Dolan believes that raising the individual awards might encourage both students and mentors.

Guthrie reported on progress changing the three Academy Trust accounts from Bank One to Merrill-Lynch. Forms from Merrill-Lynch have been signed by the Trustees, but Bank One wants a letter signed by Guthrie.

Jackson reminded members of the 18–19 February 2000 retreat at St. Mary of the Woods College, and distributed the agreement form between the college and IAS, following up on the Howes and Jackson 7 October 1999 letter to the Executive Committee. Academy Committee Chairs are also invited and encouraged to contact their members for suggestions on topics to be considered at the retreat to develop a 5-year plan. Howes asked Guthrie for a ball-park figure on IAS research funds available. Guthrie replied $100,000 per year unless we go for higher amount.

Under new business Jones brought up the proposed IAS resolution (mailed earlier to members) on the teaching of evolution, indicating a State Representative in northeastern Indiana may bring a Kansas-like bill before the legislature. After some modifications to the resolution, Frazier moved we accept resolution, seconded by Howes, and unanimously approved.

Jackson read a letter from Al Lindsey, thanking him for mailing a 1967 IAS Program to him, the year Al was President.

Shaffer read a resolution thanking the University of Southern Indiana for hosting the 1999 Spring and Fall IAS meetings. Frazier moved approval and Howes seconded. Unanimous.

Shaffer reminded the Committee that his term of office as Executive Director ends at the end of December and left the meeting. Jackson pointed out that the office of the Executive Director was established about eight years ago, and Nelson is the fourth Director, the previous three being Winslow, Melhorn, and Lovell. After discussion, Frazier moved, and Howes seconded, that we reappoint Shaffer as Executive Director, subject to review. Unanimous.

Jackson closed meeting at 3:00 PM.

COUNCIL MEETING
University of Southern Indiana
4 November 1999

President Marion Jackson opened the meeting at 3:10 PM in the University Center, and asked members for a standing introduction. Members present, in addition to those listed for the Executive Committee meeting, were: James Bandoli, Clare Chatot, Dick Conklin, David Daniell, Kris Dhawale, William Gommel, Ellen Jacquart, Blake Janutolo, Nils Johansen, Jim Mitchell, Damian Schmelz, Robert Waltz, Melissa Warden, and Dan Webster.

Jackson asked if there were any additions or corrections to the minutes for the 16 April 1999 Council meeting. Minutes were approved.

Frazier distributed and reviewed the budget for 1 January–31 October 1999.

McKnight reported that Gary Dolph will not continue editorship of the *Proceedings*. He has done a lot of work the last nine years and will be sorely missed.

Berry reported that the next issue of the newsletter will be in late December or early January. Deadline for articles is 15 December.

Howes needs input for appointments to committees. If you need money, 20 November is the deadline for requests to be considered at the 4 December 1999 budget meeting.

Jackson reviewed the two special Executive meetings (as in Executive Committee meeting minutes) and invited committee chairpersons to attend the retreat at St. Mary of the Woods College 18–19 February 2000.

Shaffer distributed the membership summary, read the thank you resolution to be read at the annual meeting, and asked for suggestions of Indiana outstanding scientists for the state museum.

Schmelz distributed a report on activities of the Natural Resources Commission and also asked for suggestions on the IAS museum display.

Gommel reported nine deaths of IAS members and former members whose names would be read at the necrology service at the annual meeting, and asked that all members send resumes to Shaffer or himself to create a file for future use.

Guthrie reported that the Trustees are moving the three trust accounts from Bank One to Merrill-Lynch for a saving of about $17,000.

Chatot distributed the 1999 Annual Report of the IAS Research Grants Committee, and pointed out that her term as Chair ends this December and that a new committee chair will be appointed for next year. The guidelines for research proposals were published in the 1999 IAS Yearbook, and she will talk to teachers attending the Junior Academy meeting tomorrow about some of the committee concerns about better definition of the Junior research proposals. The following discussions involved raising the dollar limit on research proposals and getting more detailed final reports on the research, such as abstracts. This will definitely be discussed at the retreat.

Webster distributed the recommendations of the awards committee: Special Service Award, Holly Oster; Fellows, Rebecca Dolan and Melissa Warden; and Emeritus Member, Benjamin Moulton. Approved.

Jacquart distributed a flier on "Invasive Plants in Indiana" with alternative native plants to replace them, now ready for printing (with IAS funds approved at last year's budget meeting). She had arranged for the biological sections of IAS to have a joint session on establishing the Indiana Biological Survey: Purpose, Scope and Mission at 11:00 AM tomorrow, with John Whittaker leading off with the history, Thomas Simon with the plans, and Ron Hellenthal with the database model to tie all biological collections together. Jacquart will meet the 20 November deadline for budget proposals.

Oster distributed her 1999 annual report on the holdings of the IAS Wright Memorial Library and other activities, including state funds of $17,622 received for publishing Vols. 108 and 109 of the IAS *Proceedings*, and that there were 899 file transfers from the IAS webpage in September 1999.

Conklin advised that the winning candidates for next year's IAS officers were Edwin Squiers for President-Elect, Edward Frazier as Treasurer, and Tracy Branam on Research Grants. Only 20% of the IAS members voted.

The 2000 IAS meeting sites will be at Indiana University East at Richmond, and the 2001 meetings at IU-Purdue at Fort Wayne.

McKnight reported on the status of publications.

Jones distributed his handout to members not at the Executive meeting, reviewed it briefly, and announced that Linda Airey was quitting as Director of the Junior Academy.

Shutt asked for suggestions for Speaker of the Year for 2000.

The proposed resolution for the continued teaching of evolution in the schools of Indiana, and not "creation science" was discussed and further edited. Schmelz moved that the resolution be read at the annual meeting, seconded by Chatot, and passed unanimously.

McKnight distributed a summary of IAS attendance and abstracts presented at the fall meeting for each of the sections (16) by years 1985–1999 for future planning. Chemistry and Ecology had the highest average number of abstracts at 21, History of Science the lowest at 4.

Jackson closed the meeting at 5:25 PM.

115th ANNUAL MEMBER'S MEETING
5 November 1999

After Dr. H. Ray Hoops, President of the University of Southern Indiana, welcomed the members of the IAS to the campus, the Speaker of the Year, Dr. James O. Farlow, gave an interesting talk on dinosaur footprints. President Marion Jackson then opened the 115th Annual Meeting in Carter Hall, University Center at 1:15 PM by reading the following resolution:

> Whereas; the members of the Indiana Academy of Science are deeply grateful for the invitation to hold the 115th annual meeting of the Academy on the campus of the University of Southern Indiana, at Evansville; and
>
> Whereas; the administration, faculty, staff, and students of the University of Southern Indiana have cooperated admirable in providing their facilities, resources, and support for this

115th annual meeting of the Indiana Academy of Science; be it

Resolved; that the Academy members here assembled express their sincere appreciation to Dr. H. Ray Hoops, President, and Dr. Jerome R. Cain, Dean of Science of the Pott School of Science and Engineering Technology, for all the courtesies that have been extended to the Academy during this meeting. We are especially grateful to Dr. James H. Bandoli and Dr. Nils I. Johansen, chairpersons of the local planning committee, to all the members of the committee, and to other facilitators for the arrangements of the entire program and for the comfort and conveniences provided Academy members and guests. We also express our sincere thanks to all Academy members who organized and participated in activities associated with this 115th annual meeting of the Indiana Academy of Science.

Respectfully submitted,
Marion T. Jackson, President, IAS

Jackson then introduced Richard Conklin, Chair of Nominations and Elections, who presented the election results: Edwin Squiers, President-Elect; Edward Frazier, Treasurer; Academy Foundation Trustee, Frank Guthrie; and Research Grants, Tracy Branam.

Jackson announced that Nelson Shaffer has been reappointed as Executive Director. Gary Dolph is resigning the editorship of the *Proceedings* of the IAS, and anyone interested in this position should contact him, Howes, or McKnight.

Webster moved that Ben Moulton be named Emeritus Member. The vote for was unanimous. He also moved that Rebecca Dolan and Melissa Warden be named Fellows of the IAS. Unanimous approval. Holly Oster has been given the Special Service Award.

Gommel, as Historian, encouraged all IAS members to send their resumes to him or Shaffer and, as necrologist, also any obituaries they see for other members to him, Jim Berry for newsletter, or Shaffer. He then read the names of IAS members who have died since the last annual meeting: Lois Burton, Robert Ferris Duncan, Howard Michaud, R. Vincent Cash, Alan Horowitz, Sherman Minton, Thomas A. Cole, May Kolmer Schaefer Iske, and Raymond J. Russo. Members then stood for a moment of silence to honor these, our departed colleagues, for their contributions to the IAS and the scientific community.

Jackson then read the following resolution, which had been passed by the Executive Committee and Council yesterday: Recognizing that efforts exist in the State of Indiana to remove any emphasis on, and references to, evolution and cosmology from its state education programs, the following Resolution is proposed for adoption by the Indiana Academy of Science at its annual Fall Meeting – 5 November 1999.

> Whereas evolution is a major scientific principle based upon much factual evidence, it should continue to be taught in schools, colleges, and universities of Indiana, just as major concepts of cells, atoms, and stars are taught; and
>
> Whereas neither creationism nor "Creation Science" should be taught as science because both are based, at least partially, upon beliefs which are not supported by observed facts; and
>
> Whereas, learning and inquiry are severely inhibited if teachers are placed in a position where they may feel pressured to alter their teaching of the fundamental concepts of science in response to demands external to scientific disciplines,
>
> Therefore, be it resolved that the Indiana Academy of Science, as a part of its commitment to educational excellence in science instruction, opposes any restriction on the teaching of biological and cosmic evolution in the curricula of Indiana's educational institutions.

The above resolution was adopted unanimously. In response to a question on what will be done with this resolution, Jackson responded that this will be one of the items discussed at the IAS Executive Committee and Committee Chairperson retreat to be held 18–19 February 2000. Jackson also informed the membership that the Executive Committee had two special meetings this year, one with the Trustees of the Academy Foundation on getting more IAS research funding and one with the Biodiversity and Natural Areas Committee on rejuvenation of the biological survey, both of which led to the need for a winter retreat to develop a five-year plan for the Academy.

The Spring (14–15 April) and Fall (2–3 November) 2000 IAS meetings will be held at Indiana University East in Richmond.

For the continuity of the IAS, President Jackson then passed the gavel over to President-Elect Ruth Howes, who again thanked the University and the Local Arrangements Committee of Nils Johansen, Jim Bandoli, Linda Airey, Duvall Jones, and Bill McKnight for the exciting annual meeting. She also thanked President Marion Jackson for his excellent leadership this past year and adjourned the meeting at 1:50 PM.

Respectfully submitted,
Robert F. Dale Secretary, IAS

BUDGET COMMITTEE MEETING

Butler University

4 December 1999

President Ruth Howes opened the meeting at 9:30 AM in Gallahue Hall, by asking members to introduce themselves. Members present: Linda Airey, Stan Burden, Clare Chatot, Robert Dale, David Daniell, Rebecca Dolan, Edward Frazier, Frank Guthrie, Ruth Howes, Marion Jackson, Ellen Jacquart, Duvall Jones, Bill McKnight, George Mourad, Holly Oster, Donald Ruch, and Nelson Shaffer.

Howes appointed a committee to review the minutes of the Executive and Council meetings on 4 November 1999 and the Annual meeting on 5 November 1999.

Frazier moved acceptance of the year 2000 budget sent to the Budget Committee with Howes' memo of 22 November 1999. Seconded by Jacquart. Frazier then reviewed the budget, calling on Dolan for Website, Jones for Junior Academy, Howes for increasing research stipends and decreasing number of proposals funded, and Jacquart for IBS data base support. After considerable discussion and volunteered budget reductions to reduce expenditures to within about $9000 of expected revenues, Howes reminded members of the motion on the floor. Passed unanimously.

Howes asked that retreat participants think about what real science research and education services IAS can and should do in the next five years, and Jackson indicated that registration materials for the 18–19 February 2000 retreat should be out soon. McKnight reported the newsletter should be finished next week, and Jacquart distributed copies of the completed fliers on *Invasive Plants in Indiana* and *Landscaping with Plants Native to Indiana*.

Howes closed the IAS Budget meeting at 11:55 AM.

EXECUTIVE COMMITTEE
Butler University
4 December 1999

Howes opened the meeting outside Room 300 of Gallahue Hall at 12:00 noon. Members present: Robert Dale, Rebecca Dolan, Edward Frazier, Ruth Howes, Marion Jackson, Duvall Jones, and Nelson Shaffer.

Frazier moved that he be authorized to sign letters to Executive Director Shaffer, Publications Chairman McKnight, and *Proceedings* Editor Dolph for continuation of funding for 2000. Gary Dolph has agreed to continue as Editor until a successor has been found. Seconded by Dolan. Passed.

Dale read a question from a legislative survey questionnaire he had received from State Representative Sue Scholer on the teaching of evolution:

> "8. The State of Kansas recently removed evolution from a required list of topics on the state's science curriculum. Do you (1) support a ban on the teaching of evolution (2) Feel only evolution should be taught in public schools (3) Feel both creationism and evolution should be introduced and discussed equally in the classroom."

Jackson distributed a draft letter (29 November 1999) to the Governor and State Senators and Legislators about the IAS resolution on the teaching of evolution. Approved with minor editing. This letter and the resolution will be included in the IAS Newsletter.

Meeting closed at 12:20 PM.

Respectfully submitted,
Robert F. Dale, Secretary

INSTRUCTIONS TO AUTHORS

(revised October 2001)

General information.—Manuscripts and all correspondence should be sent to the Editor. To be eligible for publication in the *Proceedings*, at least one author must be a member of the Academy. Papers that have been presented at an Academy meeting may be given preference for publication. Submission of a manuscript to the Editor implies that it has not been sent to another publication, nor has it been published elsewhere. If it is accepted for publication in the *Proceedings*, it may not be republished without the written consent of the Academy.

All manuscripts are evaluated by referees. Submit three copies of the manuscript. Figures in manuscripts for review may be submitted as photocopies, and they should be approximately the size that they will be printed in the *Proceedings*.

After the manuscript has been accepted, the author will be asked to submit the manuscript as a paper copy and on a computer disc in a widely-used word processing program. Indicate clearly on the computer disc the **word processing program** and the **type of computer** (Mac or PC).

Galley proofs will be sent to the primary author for approval and correction.

Style.—Do not use right or full justification. Also, use a non-proportional font (e.g, Courier, but not Times Roman).

Title page.—The title page should include (1) the title in capital letters, (2) each author's name and address, (3) the running head (see below), and (4) the complete name, address, and telephone number of the author with whom proofs and correspondence should be exchanged, a FAX number and electronic mail address if available.

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Citation of references in the text: Cite only papers already published or in press. Include within parentheses the surname of the author followed by the date of publication. A comma separates multiple citations by the same author(s) and a semicolon separates citations by different authors, e.g., (Smith 1990), (Jones 1988; Smith 1993), (Smith 1986, 1987; Smith & Jones 1989; Jones et al. 1990).

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Walter, J. & B. Hallet. 1979. Geometry of former subglacial water channels and cavities. Journal of Glaciology 23:335–346.

Walter, J. 1992. The significance and complexity of communication in moths. Pp. 25–66, *In* Insect Communications: Mechanisms and Ecological Significance. (P.N. Work & J.S. Rivers, eds.). Princeton University Press, Princeton, New Jersey.

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Legends for illustrations should be placed together on the same page(s) and separate from the illustrations. Each plate must have only one legend, as indicated below:

Figures 1–4.—Right chelicerae of species of *Centruroides* from Timbuktu. 1. Dorsal view; 2. Prolateral view of moveable finger; 3. *Centruroides* holotype male; 4. *Centruroides* male. Scale = 1.0 mm.

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